This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

GUIDE TO THE MINERAL COLLECTIONS IN THE ILLINOIS STATE MUSEUM

STATE OF ILLINOIS
FRANK O. LOWDEN, GOVERNOR

DEPARTMENT OF REGISTRATION AND EDUCATION
FRANCIS W. SHEPARDSON, PH.D., LL.D., DIRECTOR

STATE MUSEUM DIVISION
A. R. CROOK, PH.D., CHIEF
SPRINGFIELD

A FREE INSTITUTION FOR THE PEOPLE:

To PROMOTE SCIENCE
To PROMOTE ART
To PROMOTE BUSINESS

Hours:

Week Days: 8 A.M. till 12 noon, 1:30 P.M. till 5 P.M.
Saturdays: 8 A.M. till 3 P.M.

LETTER OF TRANSMITTAL

STATE MUSEUM, SPRINGFIELD
August 31, 1919

Francis W. Shepardson, LL.D.
Director, Department of Registration and Education

DEAR SIR:

For the purpose of increasing the usefulness of the collections in the State Museum a series of guidebooks was planned a few years ago. The first to be printed was the *General Guide,* which appeared in 1914 and which is now exhausted. Herewith is submitted a *Guide to the Mineral Collections,* upon which the chief has been working in moments which could be spared from other work for the past several years.

Hoping that it may prove of service to students of mineralogy and also to those visitors whose interest is of a general character, I am

Yours very respectfully,

A. R. CROOK,
Chief, State Museum Division

GUIDE TO THE
MINERAL COLLECTIONS
IN THE
ILLINOIS STATE MUSEUM

By

A. R. CROOK, PH.D.
Chief, State Museum Division, Department of Registration and Education

---

SPRINGFIELD, ILLINOIS
1920

Published October 1920

Composed and Printed By
The University of Chicago Press
Chicago, Illinois, U.S.A.

PREFACE

In the following pages an attempt has been made to so describe the minerals constituting our constantly growing collections as to emphasize the most important ones and at the same time to present to the reader a good idea of the science of mineralogy. The average visitor approaches the subject as a child would and just as the human race has done. When early man wandered up stream courses and found a gold nugget he doubtless was attracted by its yellow color, in time noticed the weight, softness, etc., and learned to use it as an ornament. The child does the same, using the senses of sight, feel, taste, and smell in making the acquaintance of any strange substance. Hence the physical characteristics—form, color, hardness, and weight—of various minerals are described, and then their chemical constituents, geological and geographical relations, and use are given. By becoming acquainted with various minerals the visitor obtains a knowledge of the science.

In preparation of this work the writer has used chiefly Dana's, Mier's, Lacroix's, and Tschermak's mineralogies and Tutton's and Groth's crystallographies, in addition to individual articles in U.S.G.S. reports, scientific journals, etc.

Especial thanks are due Professor O. C. Farrington for painstaking revision of the manuscript, Professor W. S. Bayly for careful reading of the proof, and the University of Chicago Press for the thorough manner in which their part of the work has been done.

Professor Farrington supplied photographs for Plates IV, XVIII, XIX*a*, and XXVII*a*. Plate VI*b* is after W. M. Foote, and Plate I*a* is reproduced by permission of B. F. Buck & Co. The other illustrations are by the writer.

A. R. CROOK

August, 1919

TABLE OF CONTENTS

	PAGE
LIST OF ILLUSTRATIONS	xiii
ABBREVIATIONS	xxi
INTRODUCTION	1
CLASS I. ELEMENTS	5
LIST OF ELEMENTS AND THEIR ATOMIC WEIGHTS	45
CLASS II. SULPHIDES	46
CLASS III. SULPHANTIMONITES, SULPHARSENITES	68
CLASS IV. HALOIDS	76
CLASS V. OXIDES	82
CLASS VI. CARBONATES	112
CLASS VII. SILICATES	132
CLASS VIII. NIOBATES, TANTALATES	175
CLASS IX. PHOSPHATES, ETC.	175
CLASS X. BORATES, URANATES	177
CLASS XI. SULPHATES, CHROMATES, TELLURATES	179
CLASS XII. TUNGSTATES, MOLYBDATES	185
CLASS XIII. ORGANIC ACID SALTS	187
CLASS XIV. HYDROCARBONS	187
SUMMARY	194
NAMES OF MINERALS	196
THE USES OF MINERALS	197
HISTORY OF THE STUDY OF MINERALS	198
LIST OF MINERALS	202
INDEX	279

LIST OF ILLUSTRATIONS

PAGE

FIG. 1. MODEL OF OCTAHEDRON; PREVAILING OUTLINE OF DIAMOND 5
FIG. 2. AXES 6
FIG. 3. METHOD OF CONSTRUCTING CRYSTALLOGRAPHIC AXES . 7
FIG. 4. CONSTRUCTION OF AN OCTAHEDRAL PLANE 7
FIG. 5. COMPLETED OCTAHEDRON 8
FIG. 6. MODEL OF TRAPEZOHEDRON 9
FIG. 7. COMPLETED TRAPEZOHEDRON 9
FIG. 8. MODEL OF TRISOCTAHEDRON 10
FIG. 9. TRISOCTAHEDRON COMPLETED 10
FIG. 10. MODEL OF HEXOCTAHEDRON 12
FIG. 11. HEXOCTAHEDRON COMPLETED 12
FIG. 12. GROWTH OF UNSHADED PLANES OF THE WOODEN OCTAHEDRON PRODUCE THE GLASS TETRAHEDRON COVERING IT 12
FIG. 13. RIGHT-HANDED TETRAHEDRON 12
FIG. 14. WOODEN OCTAHEDRON INCLOSED BY GLASS TETRAHEDRON 13
FIG. 15. LEFT-HANDED TETRAHEDRON 13
FIG. 16. INTERPENETRATING SUPPLEMENTARY TETRAHEDRONS (TETRAHEDRAL TWINS) 13
FIG. 17. TETRAHEDRAL TWIN WITH CORNERS TRUNCATED . . 14
FIG. 18. MODEL OF RIGHT-HANDED HEXATETRAHEDRON . . . 15
FIG. 19. CONSTRUCTION OF HEXATETRAHEDRON 15
FIG. 20. INTERPENETRATING TRUNCATED TETRAHEDRONS BEVELED BY HEXATETRAHEDRONS 16
FIG. 21. MODEL OF "SPINEL TWIN" 17
FIG. 22. DRAWING OF SPINEL TWIN 17
FIG. 23. TWO KINDS OF AXES OF SYMMETRY 18
FIG. 24. DOTTED LINES SHOW DIRECTION OF PLANES OF SYMMETRY IN CUBE 19
FIG. 25. ANGLES OF INCIDENCE AND REFRACTION 19
FIG. 26. MODEL OF ORTHORHOMBIC BIPYRAMID 25
FIG. 27. ORTHORHOMBIC PYRAMIDAL PLANE AND AXES . . . 25
FIG. 28. OBTUSE BIPYRAMID CHARACTERISTIC OF SULPHUR . . 26
FIG. 29. MODEL OF BRACHYDOMES AND MACROPINACOIDS . . 26
FIG. 30. UPPER BRACHYDOME PLANES 26
FIG. 31. MODEL OF MACRODOMES AND BRACHYPINACOIDS . . . 27
FIG. 32. UPPER MACRODOMES 27

PAGE
FIG. 33. PRISM AND BASAL PLANES 27
FIG. 34. BASE, MACROPINACOID, AND BRACHYPINACOID . . . 28
FIG. 35. MODEL OF BASE, MACRO- AND BRACHYPINACOID . . . 28
FIG. 36. MODEL OF PRISM, BRACHYPINACOID, AND BRACHYDOME . 28
FIG. 37. RIGHT-HANDED SPHENOID 28
FIG. 38. SULPHUR, USUAL HABIT 29
FIG. 39. SULPHUR, SPHENOIDAL HABIT 29
FIG. 40. AXES OF MONOCLINIC CRYSTAL 30
FIG. 41. CUBE 33
FIG. 42. TETRAHEXAHEDRON MODEL 35
FIG. 43. CONSTRUCTION OF TETRAHEXAHEDRON 35
FIG. 44. MODEL OF A DODECAHEDRON 39
FIG. 45. CONSTRUCTION OF A DODECAHEDRON 40
FIG. 46. STIBNITE CRYSTAL 47
FIG. 47. CUBE TRUNCATED BY OCTAHEDRON 49
FIG. 48. MODEL OF CUBE TRUNCATED BY OCTAHEDRON . . . 49
FIG. 49. GALENA, JO DAVIESS COUNTY, ILLINOIS 50
FIG. 50. MODEL OF PLANES APPEARING ON GALENA 50
FIG. 51. TWIN LAMELLAE IN GALENA 51
FIG. 52. SPHALERITE 53
FIG. 53. MODEL OF THREE-FACED TETRAHEDRON, A TRISTETRAHEDRON 54
FIG. 54. CONSTRUCTION OF TRIGONAL TRISTETRAHEDRON . . . 54
FIG. 55. SPHALERITE 54
FIG. 56. ACUTE PRIMARY BIPYRAMID 57
FIG. 57. OBTUSE PRIMARY BIPYRAMID 57
FIG. 58. MODEL OF SECONDARY BIPYRAMID 58
FIG. 59. DITETRAGONAL BIPYRAMID 58
FIG. 60. MODEL OF DITETRAGONAL BIPYRAMID 58
FIG. 61. PRIMARY PRISM 59
FIG. 62. SECONDARY PRISM 59
FIG. 63. MODEL OF DITETRAGONAL PRISM 59
FIG. 64. COMBINATION OF PRIMARY PRISM, SECONDARY PRISM, SECONDARY BIPYRAMID, AND DITETRAGONAL BIPYRAMID 59
FIG. 65. MODEL OF BISPHENOID 60
FIG. 66. CHALCOPYRITE 60
FIG. 67. CHALCOPYRITE, FRENCH CREEK, PENNSYLVANIA . . . 60
FIG. 68. CHALCOPYRITE, NEUDORF 61
FIG. 69. PYRITOHEDRON DERIVED BY DISAPPEARANCE OF TETRAHEXAHEDRAL PLANES DARKENED, AND GROWTH OF THE OTHER PLANES 62
FIG. 70. MODEL OF A DIPLOID 62
FIG. 71. MODEL OF COMBINATION OF PYRITOHEDRON AND CUBE . 63

PAGE
FIG. 72. MARCASITE 64
FIG. 73. MARCASITE 64
FIG. 74. "SPEARHEAD PYRITES" 65
FIG. 75. "COCKSCOMB PYRITES" 65
FIG. 76. ARSENOPYRITE 67
FIG. 77. ARSENOPYRITE 67
FIG. 78. SYMMETRY PLANES OF A DITRIGONAL POLAR CRYSTAL . 68
FIG. 79. AXES OF HEXAGONAL SYSTEM 68
FIG. 80. MODEL OF PRIMARY PYRAMID 69
FIG. 81. BASAL SECTION SHOWING RELATION OF PRIMARY, SECONDARY, AND DIHEXAGONAL PYRAMIDS AND PRISMS . . 69
FIG. 82. MODEL OF DIHEXAGONAL BIPYRAMID 69
FIG. 83. MODEL OF PRIMARY HEXAGONAL PRISM 70
FIG. 84. SECONDARY HEXAGONAL PRISM 70
FIG. 85. MODEL OF DIHEXAGONAL PRISM 70
FIG. 86. RHOMBOHEDRON RESULTING FROM DISAPPEARANCE OF DARKENED PLANES OF THE INTERIOR FIGURE—HEXAGONAL BIPYRAMID 71
FIG. 87. MODEL OF POSITIVE SCALENOHEDRON 71
FIG. 88. MODEL OF SCALENOHEDRON TRUNCATED BY RHOMBOHEDRON 71
FIG. 89. MODEL OF TRUNCATED PRISM 71
FIG. 90. PYRARGYRITE, CRYSTAL FORM 72
FIG. 91. PREVAILING FORM OF TETRAHEDRITE 73
FIG. 92. CHARACTERISTIC FORM OF TETRAHEDRITE 73
FIG. 93. TENNANTITE (SCHWATZITE) 74
FIG. 94. MODEL OF SANDBERGERITE 74
FIG. 95. HALITE CUBE FROM SALT BRINE 77
FIG. 96. FLUORITE 78
FIG. 97. FLUORITE 78
FIG. 98. MODEL OF FLUORITE TWIN 79
FIG. 99. QUARTZ; PRISM AND RHOMBOHEDRON 83
FIG. 100. QUARTZ 83
FIG. 101. A FORM OF QUARTZ COMMON AT ALSTON MOOR, ENGLAND 83
FIG. 102. QUARTZ 83
FIG. 103. QUARTZ; POSITIVE LEFT TRIGONAL TRAPEZOHEDRON . 84
FIG. 104. QUARTZ; POSITIVE RIGHT TRIGONAL TRAPEZOHEDRON . 84
FIG. 105. TWO RIGHT-HANDED QUARTZ CRYSTALS TWINNED . . 85
FIG. 106. BRAZIL TWIN; RIGHT- AND LEFT-HANDED QUARTZ CRYSTALS INTERPENETRATING 85
FIG. 107. BRAZIL TWIN. TWO RIGHT-HANDED CRYSTALS JUXTAPOSED 86
FIG. 108. QUARTZ; BOURG DE OISANS TWIN 86

PAGE
FIG. 109. QUARTZ ETCHED WITH HYDROFLUORIC ACID; A, LEFT-HANDED; B, RIGHT-HANDED 86
FIG. 110. AIRY'S SPIRAL IN RIGHT-HANDED CRYSTAL 88
FIG. 111. CUPRITE 92
FIG. 112. ZINCITE 93
FIG. 113. CORUNDUM 94
FIG. 114. CORUNDUM 95
FIG. 115. CORUNDUM WITH TWINNING LAMELLAE PARALLEL TO *R* . 95
FIG. 116. CROSS-SECTION OF DICHROSCOPE 96
FIG. 117. DIRECTION OF VIBRATION OF TWO RAYS OF LIGHT PASSING THROUGH CALCITE PRISM 96
FIG. 118. RUBY 97
FIG. 119. SAPPHIRE 97
FIG. 120. MODEL OF RHOMBOHEDRON 98
FIG. 121. HEMATITE 99
FIG. 122. TABULAR HEMATITE CRYSTAL TWINNED PARALLEL TO THE PRISM 99
FIG. 123. MANGANITE 100
FIG. 124. MANGANITE 100
FIG. 125. GOETHITE 102
FIG. 126. GOETHITE 102
FIG. 127. SPINEL TWIN 105
FIG. 128. SPINEL 105
FIG. 129. MAGNETITE 106
FIG. 130. CASSITERITE 108
FIG. 131. CASSITERITE 108
FIG. 132. RUTILE 109
FIG. 133. RUTILE TRIPLET 110
FIG. 134. RUTILE OCTET 110
FIG. 135. CALCITE. POSITIVE RHOMBOHEDRON; CLEAVAGE RHOMBOHEDRON 113
FIG. 136. CALCITE. NEGATIVE RHOMBOHEDRON 113
FIG. 137. CALCITE. NEGATIVE ACUTE RHOMBOHEDRON . . . 114
FIG. 138. CALCITE, SCALENOHEDRON 114
FIG. 139. CALCITE, PRISM AND NEGATIVE OBTUSE RHOMBOHEDRON 114
FIG. 140. CALCITE, SHOWING PRISM, NEGATIVE OBTUSE RHOMBOHEDRON, AND BASE 114
FIG. 141. CALCITE; COMBINATION OF SCALENOHEDRON AND RHOMBOHEDRON 114
FIG. 142. CALCITE RHOMBOHEDRON 114
FIG. 143. CALCITE SCALENOHEDRON 115
FIG. 144. CALCITE SCALENOHEDRON 115

PAGE
FIG. 145. CALCITE PRISM 115
FIG. 146. CALCITE SCALENOHEDRON 116
FIG. 147. CALCITE SCALENOHEDRON 116
FIG. 148. CALCITE ETCHED WITH DILUTE HYDROCHLORIC ACID . 118
FIG. 149. DOLOMITE ETCHED WITH DILUTE HYDROCHLORIC ACID . 118
FIG. 150. ELASTICITY COEFFICIENT OF CALCITE 119
FIG. 151. ELASTICITY COEFFICIENT OF DOLOMITE 119
FIG. 152. GLIDE PLANES IN CALCITE 119
FIG. 153. ARAGONITE 123
FIG. 154. BASAL SECTION OF ARAGONITE TRIPLET 124
FIG. 155. BASAL SECTION OF ARAGONITE; INTERPENETRANT TRIPLET 124
FIG. 156. WITHERITE 125
FIG. 157. CROSS-SECTION OF WITHERITE 125
FIG. 158. CERUSSITE 127
FIG. 159. CERUSSITE 127
FIG. 160. THREE CERUSSITE CRYSTALS INTERPENETRATING PARALLEL TO PRISM PLANES 127
FIG. 161. AXES OF MONOCLINIC CRYSTAL 128
FIG. 162. MONOCLINIC BIPYRAMID 129
FIG. 163. ORTHODOMES AND CLINODOMES 129
FIG. 164. MODEL OF PRISM AND BASAL PLANE 130
FIG. 165. MALACHITE SECTION 130
FIG. 166. AZURITE CRYSTAL, SHOWING ALSO POSITION OF OPTIC AXES AND AXIAL PLANE 131
FIG. 167. MODEL OF AN ORTHOCLASE CRYSTAL 134
FIG. 168. ORTHOCLASE 134
FIG. 169. ADULARIA ORTHOCLASE 134
FIG. 170. MODEL OF CARLSBAD TWIN, INTERPENETRATING . . 134
FIG. 171. BAVENO TWIN, COMPOSITION FACE 134
FIG. 172. MANEBACH TWIN, COMPOSITION FACE 134
FIG. 173. ORTHOCLASE SECTION; AXIAL PLANE, ANGLE OF EXTINCTION 135
FIG. 174. ORTHOCLASE (ADULARIA); AXIAL PLANE 136
FIG. 175. ORTHOCLASE; POSITIVE AND NEGATIVE DIRECTION OF EXTINCTION 136
FIG. 176. TRICLINIC AXES OF COPPER SULPHATE; NO AXES AT RIGHT ANGLES 139
FIG. 177. ALBITE 140
FIG. 178. ALBITE, SHOWING ALBITE LAW 140
FIG. 179. ALBITE, PERICLINE TWIN 141
FIG. 180. ALBITE; AXIAL PLANE 141
FIG. 181. ALBITE SECTION 141

PAGE
FIG. 182. ALBITE SECTION 141
FIG. 183. RHOMBIC SECTION OF ANORTHITE 142
FIG. 184. ANORTHITE, SHOWING POSITION OF AXIAL PLANE AND BISECTRIX 142
FIG. 185. MICROSCOPIC SECTION OF LEUCITE BETWEEN CROSSED NICOLS 145
FIG. 186a. DIOPSIDE 147
FIG. 186b. PHOTOGRAPH OF DIOPSIDE FROM CANTLEY, QUEBEC, CANADA 147
FIG. 187. DIOPSIDE 148
FIG. 188. DIOPSIDE, SHOWING OPTIC AXES, ACUTE BISECTRIX, AXES OF ELASTICITY 148
FIG. 189. AUGITE 148
FIG. 190. AUGITE TWIN 148
FIG. 191. AUGITE CROSS-SECTION PERPENDICULAR TO PRISM PLANES 149
FIG. 192. ENSTATITE, SHOWING PARALLEL EXTINCTION . . . 149
FIG. 193. DIOPSIDE, SHOWING OBLIQUE EXTINCTION ANGLE . . 149
FIG. 194. RHODONITE 151
FIG. 195. ANTHOPHYLLITE, AXIAL PLANE AND OPTIC AXES . . 152
FIG. 196. HORNBLENDE 154
FIG. 197. HORNBLENDE 154
FIG. 198. HORNBLENDE SECTION PERPENDICULAR TO PRISM . . 154
FIG. 199. HORNBLENDE 154
FIG. 200. ANTHOPHYLLITE; PARALLEL EXTINCTION 155
FIG. 201. TREMOLITE; EXTINCTION ANGLE 155
FIG. 202. HORNBLENDE; EXTINCTION ANGLE 155
FIG. 203a. PHOTOGRAPH OF BERYL FROM BRAZIL 157
FIG. 203b. BERYL 157
FIG. 204. GARNET 158
FIG. 205. GARNET 159
FIG. 206. GARNET 159
FIG. 207. ZIRCON 161
FIG. 208. ZIRCON 161
FIG. 209. TOPAZ 162
FIG. 210. TOPAZ, SHOWING OPTIC AXES AND AXIAL PLANE . . 162
FIG. 211. TOURMALINE 164
FIG. 212. TOURMALINE 164
FIG. 213. TOURMALINE, ANALOGOUS END 165
FIG. 214. FOUR-TWINNED CRYSTALS OF STILBITE 166
FIG. 215. STILBITE SHEAF. 166
FIG. 216. LEUCITE 167
FIG. 217. NATROLITE 168

PAGE
FIG. 218. MUSCOVITE 169
FIG. 219. MUSCOVITE: PRESSURE FIGURE, PERCUSSION FIGURE, OPTIC AXES 169
FIG. 220. BIOTITE; AXIAL PLANE 171
FIG. 221. BASAL SECTION OF BIOTITE, SHOWING POSITION OF AXIAL PLANE AND PERCUSSION FIGURE 171
FIG. 222. APATITE 175
FIG. 223. BARITE 179
FIG. 224. BARITE 179
FIG. 225. BARITE 179
FIG. 226. CELESTITE 180
FIG. 227. ANGLESITE 181
FIG. 228. ANGLESITE 181
FIG. 229. GYPSUM 182
FIG. 230. GYPSUM 182
FIG. 231. GYPSUM 182
FIG. 232. GYPSUM TWINNED BY JUXTAPOSITION 183
FIG. 233. GYPSUM, TWINNED BY INTERPENETRATION 183
FIG. 234. WOLFRAMITE 185
FIG. 235. WULFENITE 186
FIG. 236. WULFENITE 186

PLATE I. *a*, PREVAILING FORMS OF THE DIAMOND. G. F. WILLIAMS COLLECTION; *b*, GLASS MODEL OF CULLINAN DIAMOND, THE LARGEST DIAMOND EVER FOUND.
PLATE II. CONSTRUCTION OF RIGHT-HAND UPPER OCTANT OF TRISOCTAHEDRON ABOVE AND OF TRAPEZOHEDRON BELOW.
PLATE III. CONSTRUCTION OF ONE OCTANT OF HEXOCTAHEDRON.
PLATE IV. DENDRITIC COPPER FROM CALUMET AND HECLA MINING REGION, MICHIGAN.
PLATE V. MUKEROP METEORITE, ONE-SIXTH NATURAL SIZE. FELL IN AMALIA-GOAMUS, WEST AFRICA.
PLATE VI. *a*, STIBNITE, JAPAN; *b*, MOLYBDENITE FROM ALDFIELD, PONTIAC COUNTY, QUEBEC, CANADA.
PLATE VII. *a*, GROUP OF PYRITE CUBES, SHOWING STRIATIONS, CENTRAL CITY, COLORADO; *b*, PYRITE. A PYRITOHEDRON AND CUBES, COLORADO.
PLATE VIII. MARCASITE, JO DAVIESS COUNTY, ILLINOIS.
PLATE IX. MARCASITE DISKS, GULF MINE, SPARTA, RANDOLPH COUNTY, ILLINOIS.

PLATE X. MARCASITE, SHOWING RADIATED INTERNAL STRUCTURE.

PLATE XI. MARCASITE COATING GALENA, MARSDEN MINE, JO DAVIESS COUNTY, ILLINOIS.

PLATE XII. FLUORITE GROUP FROM ROSICLARE, HARDIN COUNTY, ILLINOIS.

PLATE XIII. *a*, FLUORITE CUBES, ROSICLARE, ILLINOIS; *b*, OCTAHEDRONS CLEAVED OUT BY TEN-YEAR-OLD BOY, SHOWING EASE AND REGULARITY OF CLEAVAGE.

PLATE XIV. *a*, SMOKY QUARTZ, "CAIRNGORM," FROM MONTANA; *b*, QUARTZ, MONTGOMERY COUNTY, ARKANSAS.

PLATE XV. QUARTZ GROUP, MONTGOMERY COUNTY, ARKANSAS.

PLATE XVI. QUARTZ, "BOURG DE OISANS" TWIN, HOT SPRINGS, ARKANSAS.

PLATE XVII. AMETHYST, THUNDER BAY, LAKE SUPERIOR.

PLATE XVIII. MOSS AGATE, INDIA.

PLATE XIX. *a*, BOTRYOIDAL HEMATITE, CUMBERLAND, ENGLAND; *b*, LIMONITE, HARDIN COUNTY, ILLINOIS.

PLATE XX. CALCITE, WEBB CITY, MISSOURI.

PLATE XXI. *a*, CALCITE, "DOG-TOOTH SPAR," JOPLIN, MISSOURI; *b*, CALCITE, "ICELAND SPAR," SHOWING DOUBLE REFRACTION.

PLATE XXII. CALCITE, JOPLIN, MISSOURI.

PLATE XXIII. CALCITE SCALENOHEDRON, ROSSIE, ST. LAWRENCE COUNTY, NEW YORK.

PLATE XXIV. *a*, CALCITE, JOPLIN, MISSOURI; *b*, QUARTZ GEODE WITH LARGE FLAT RHOMBOHEDRAL CRYSTALS, ST. FRANCISVILLE, MISSOURI.

PLATE XXV. *a*, ARAGONITE CRYSTALS FOUR INCHES IN DIAMETER, CIANCIANA, SICILY; *b*, STALACTITES, BISBEE, ARIZONA.

PLATE XXVI. *a*, MICROCLINE, "AMAZON STONE," PIKE'S PEAK, COLORADO; *b*, MICROCLINE, PIKE'S PEAK, COLORADO.

PLATE XXVII. *a*, GARNETS; DODECAHEDRON FROM SALIDA, COLORADO, TRAPEZOHEDRON FROM NORTH CAROLINA, AND COMBINATION FROM FORT WRANGEL, ALASKA; *b*, A DODECAHEDRON NEARLY FOUR INCHES IN DIAMETER FROM SALIDA, COLORADO.

PLATE XXVIII. *a*, TOURMALINE DOUBLY TERMINATED; VARIOUSLY COLORED CRYSTAL FROM MESA GRANDE, CALIFORNIA; *b*, BLACK, WELL-CRYSTALLIZED SPECIMEN FROM HADDAM, CONNECTICUT.

PLATE XXIX. *a*, APATITE, RENFREW, CANADA; *b*, BARITE, ALSTON MOOR, ENGLAND.

PLATE XXX. GYPSUM, SHOWING FISHTAIL TWIN AND CURLED FORM.

PLATE XXXI. GYPSUM, "SELENITE," WAYNE COUNTY, UTAH.

ABBREVIATIONS

a, b, c = Crystallographic axes
$\mathfrak{a}, \mathfrak{b}, \mathfrak{c}$ = Direction of greatest, medium, and least elasticity
α, β, γ = Greatest, medium, and least index of refraction
α, β, γ = Angles between crystallographic axes
ϵ = Direction of the extraordinary ray or its index of refraction
$2E$ = Apparent value of axial angle in the air
$\gamma - \alpha$ = Maximum birefraction
$2H$ = Value of axial angle when mineral is immersed in oil
n = Index of refraction
ρ = Axial angle of red light
$2V$ = True value of angle between optic axes
ν = Axial angle of violet (blue) light
ω = Index of refraction of the ordinary ray

INTRODUCTION

Minerals play a large part in the annual increase in wealth and in the comfort of the inhabitants of Illinois. The state is not usually thought of as a mineral-producing region, as is Colorado, Montana, or California, and the fact is not usually known that the money value of the minerals obtained in this state exceeds that of any state west of the Mississippi River.

But such is the case. During the year preceding the world-war the total value of mineral products in Illinois amounted to more than one hundred and seventeen millions of dollars, while that of California, the nearest competitor, was only one hundred and one millions, and Colorado and Montana together fell even farther behind Illinois in mineral production.

The use of minerals is an index of civilization. Man is the only member of the animal kingdom to utilize minerals; and the more primitive his place in human society, the less does he do so.

The whole fabric of civilization depends upon iron, copper, gold, and other metals, and upon coal, building stone, and clays. The people of our state produce some of these substances in great quantities and use all kinds of minerals from all corners of the globe.

Some minerals occur in extensive deposits in the state, others are scattered here and there. The majority of those described in the following pages have been found within the region and many of the others are very useful for our people.

While more than a thousand different minerals are known, only about one hundred are common enough to claim our special attention. These one hundred are well illustrated in the museum collections.

Many visitors, while having a general idea of the subject, are unable to say just what a mineral is. Upon investigation they learn that a mineral is a natural, inorganic, homogeneous, solid, liquid, or gas. When solid, it is usually crystallized.

Artificial substances such as are produced in laboratories, chemical works, iron foundries, etc., are excluded from the definition, although they often show perfection of form and purity of constitution. Mineralogy is concerned with *natural* products.

The term inorganic excludes all forms of living substance—everything that grows by internal activity, that has the power of assimilation and reproduction, that has sensibility and usually slight chemical stability. A mineral may have had an organic origin. For example, the carbon of a piece of graphite may have been at one time in a tree. The tree died and with the loss of oxygen and hydrogen was converted into peat. The loss of oxygen and hydrogen continuing, the peat or lignite was changed into bituminous coal, then into anthracite, and finally into graphite. It is not the origin but its present condition which places a substance in the mineral kingdom.

The term homogeneous indicates that the substance throughout is the same at one point as another, has the same arrangement, and shows the same properties. This separates a mineral from other inorganic substances such as rocks. A rock is made up of a mass of minerals.

Usually a mineral is a solid. Some minerals—for example, water and mercury—are ordinarily liquid but may be changed into solids by freezing: water at 32° and mercury at −40° F. All minerals are solid under certain conditions.

Minerals are usually crystallized; that is, they have a definite internal structure which is often shown by their external form. There are a few exceptions, such as turquoise and opal, and other substances which are solidified from gases or liquids so rapidly or under such other unfavorable conditions that the molecules are unable to properly arrange themselves. These minerals are said to be amorphous. They may be regarded as minerals that are unsuccessful or are of weak molecular attractions. Ordinarily a mineral has just as definite a shape as has a bird or a flower. It has less opportunity than a flower to develop a perfect external form, since it is usually crowded by its neighbors. The growing crystal soon reaches a place where its planes touch those of its neighbors and its perfection is impaired. But though the bounding planes are distorted and irregular, the internal arrangement is so orderly and definite that the smallest fragment has the same structure as a perfect crystal.

This regularity of architecture in the mineral world is a fact of far-reaching importance. It discloses one of the great laws of the universe, a law as beautiful and universal as the law of gravitation, the conservation of energy, or the development of species.

The law of crystallization affects every particle of mineral matter in the world, and more than that, in the universe as well. The results are seen alike in the minutest forms and on a gigantic scale. The most beautiful colors in the world—the pure colors of the spectrum—are exhibited by minerals in accordance with this law.

Minerals are the most abundant and most valuable substances in the world.

If all the vegetation in the world—the great masses of weeds in Sargasso Seas, the myriads of land weeds, the flowers and grains, all the trees of the mighty forests—if all of these were placed in an immense pile and to this pile were added all the lower animals, all mankind, and all the buildings in the world, the mass would be gigantic. But, if in another pile were heaped the minerals of which the world is composed, the first pile would be as a grain of sand to a mountain, so small as to be well-nigh invisible. In quantity minerals are of the greatest importance.

In quality the same is true. They are unsurpassed in enduring beauty and value. Some diamonds like the Kohinoor, Regent, or the Cullinan are valued more highly than any other objects of the same size in the world. A ruby worth half a million dollars is so light in weight that it could be sent by mail across the continent for two cents. Mineral ornaments such as vases, tables, and columns in the palaces of the wealthy and in the great museums will remain unchanged in beauty and pleasure-giving power for many long years. Minerals are as beautiful as flowers and infinitely more permanent.

> Though the same sun with all diffusive rays
> Blush in the rose and in the diamond blaze,
> We prize the higher effort of his power
> And justly place the gem above the flower.[1]

An acquaintance with minerals is useful in many trades and professions. The doctor of medicine and the pharmacist may be interested in minerals as the source of drugs. The lawyer may be helped by some knowledge of mineralogy, especially in mining cases. The minister furnished by this science with an insight into the structure of the universe is better able to find "sermons in stones." From

---

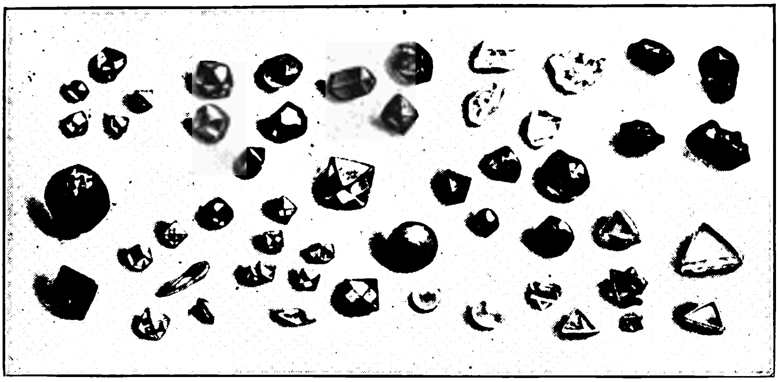
[1] Alexander Pope.

the study of the mineral composition of his soil the farmer is aided in soil improvement and in making "bread from stones." The physicist repeatedly uses minerals in his study of the laws of heat, light, and electricity. Even more dependent upon minerals as a source of materials for study and experiment is the chemist. For the geologist, the prospector, the miner, the assayer, and the metallurgist, mineralogy is a fundamental science, one without which they cannot well work.

Thus the mineral collections in the museum have a twofold claim upon the interest of the visitor: first, because they well illustrate the mineral resources of this state, and second, because they show the composition of the world and the uses which our people make of minerals to increase the comfort of living and their happiness.

The visitor will naturally begin his inspection of this collection with the minerals that are the most simple in their composition—those that are composed of but one chemical substance, the so-called elements. He will find that while there are about two dozen of them which occur in some abundance as minerals, not more than twelve are common enough to claim his attention. These are: diamond, graphite, sulphur, arsenic, antimony, bismuth, gold, silver, copper, mercury, platinum, and iron. Each of these is noteworthy because of its beauty or utility or because it shows some peculiar property. All of them except antimony, bismuth, mercury, and platinum have been found in the state. Diamond, graphite, and sulphur are non-metals; antimony and bismuth, brittle metals; gold, silver, copper, platinum, and iron, malleable metals; and mercury, a liquid metal under ordinary conditions. Together, these minerals constitute the most prominent representatives of Class I.

PLATE I



a, Prevailing forms of the diamond. G. F. Williams collection

b, Glass model of Cullinan diamond, the largest diamond ever found

CLASS I. ELEMENTS

Diamond

There are several reasons for studying the diamond first, though Illinois is not a diamond-producing state. Not more than a dozen diamonds have been found here and they are immigrants brought in by glaciers which formerly slid down from the north, carrying all kinds of minerals collected from a wide area and scattering them here and there over two-thirds of the state. The chief source of the diamond is the Kimberley region in South Africa, but no people are more partial to the diamond as a gem than are the citizens of this state. Every woman has or expects to have one, and every man should at some time buy one!

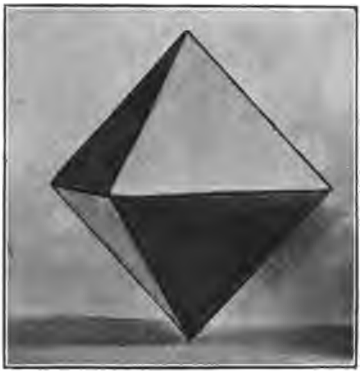


FIG. 1.—Model of octahedron; prevailing outline of diamond.

The diamond is easily premier among gems. It is a fine example of a successful mineral. Its character is positive. It deserves the most extended study. While studying it we gain an insight into the whole mineral world. The Illinois State Museum contains a few examples of the diamond, and glass models of the most famous diamonds of history. If one examines a handful of diamonds as they are taken from the mines at Kimberley (Plate I) or as they come uncut to Amsterdam, London, or New York City, he will observe that the greater number of them are shaped like two pyramids placed base to base forming an eight-sided figure called an octahedron (Fig. 1). Some of them are flat, triangular flakes, others globules, and nearly all are somewhat distorted and pitted, with some planes well developed and others small. The larger faces were formed on that side of the crystal which had the most abundant material to draw from, while the small faces, like the smaller birds in a nest, receiving the least food, have not had equal opportunity for growth. But while the different faces vary in size, the angles between them are always the same. They are said to be constant, and illustrate the "law of constancy of angle"—a law of far-reaching importance, since because of it minerals can readily be identified and classified.

The natural shape of a mineral is one of the first characters to notice. What anatomy is to the student of the human body, cell structure to the morphologist, and architecture to the builder, crystal form is to the mineralogist. It is one of the fundamentals. The purpose of study of the form of minerals is not only to recognize and picture the external form but to understand the internal structure as well, since they are dependent upon each other.

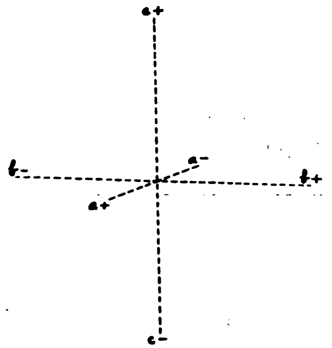


FIG. 2.—Axes

The architecture of the diamond may be better understood if the planes which occur on natural crystals can be represented by a drawing. Fortunately it is only necessary to measure off certain points and connect them by straight lines—a much simpler task than it would be to draw the structures seen in the plant and animal worlds. Anyone can draw the shapes which diamonds exhibit.

First draw three lines or *axes* which intersect each other at right angles (Fig. 2). In drawing these figures we use the method most generally employed, which is called "clinographic projection." The eye is supposed to be elevated a trifle above the crystal and removed an infinite distance so that the lines in the drawing do not converge as in ordinary perspective. Those parallel in the crystal are parallel in the drawing.

To erect the axes, a templet cut out of cardboard may be constructed in the following manner (Fig. 3):

Draw a vertical line *MM′* and *NN′* at right angles to it. Divide NN′ into six equal divisions. At the second and fourth divisions draw lines parallel to *MM'*. From *N'* mark *N'O* equal to one division. From *O* draw a straight line through *P* to *O'*. $a\bar{a}$ is the front to back axis of our crystal. From *a* draw *aR* parallel to *N'N*. From *R* draw *RP*. From *S* draw *Sb* parallel to *NN'*. From *b* draw *bP* and extend to $\bar{b}$. $b\bar{b}$ is the horizontal axis extending from right to left. Twice *OP* gives the length of the *c* axis. These axes form the foundation for the construction of the axes used all through the work. An excellent discussion of the subject may be found in Tutton's *Crystallography*.[1] We always call the vertical line (Fig. 2) *c;* the horizontal

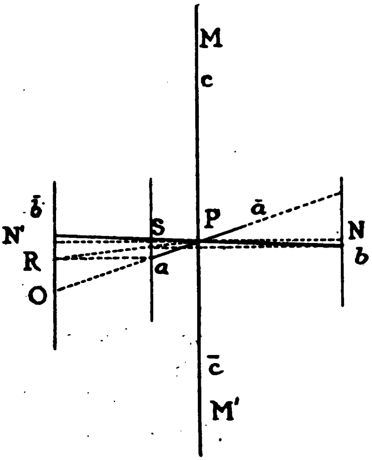


FIG. 3.—Method of constructing crystallographic axes.

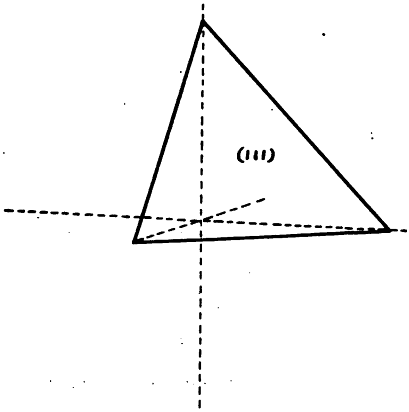


FIG. 4.—Construction of an octahedral plane.

line, extending from right to left, *b;* and the one extending from the front backward, *a*. The upper half of the *c* axis, the right half of *b*, and the front of *a* are said to be positive; the others, negative. To draw any given plane mark the points at which it would intersect the axes. In the octahedron (Fig. 1) each plane intersects the three axes at points equally distant from the center. Then to draw an octahedral plane measure off equal distances on each axis and connect these points with straight lines (Fig. 4). To complete the octahedron, which has eight such planes, draw similar planes in each of the other octants (Fig. 5).

---

[1] See pages 382–439.

The relation of the axes to each other was expressed by an English mineralogist, W. H. Miller, of Cambridge (d. 1880), as a ratio, $a:b:c$. The portion measured off on each axis is written as a denominator. Then the ratio which represents the octahedral plane is $\frac{a}{1}:\frac{b}{1}:\frac{c}{1}$, and its symbol is (111) which is read as one, one, one. When simply (111) is used, the right-hand upper octant is meant. The left-hand upper octant would have the symbol $(1\bar{1}1)$ [read one, minus one, one]; the right-hand lower $(11\bar{1})$, the left-hand lower (111), the right-hand upper back $(\bar{1}11)$, the left-hand upper back (111), etc.

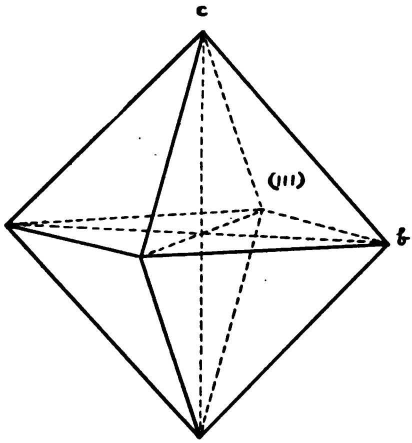
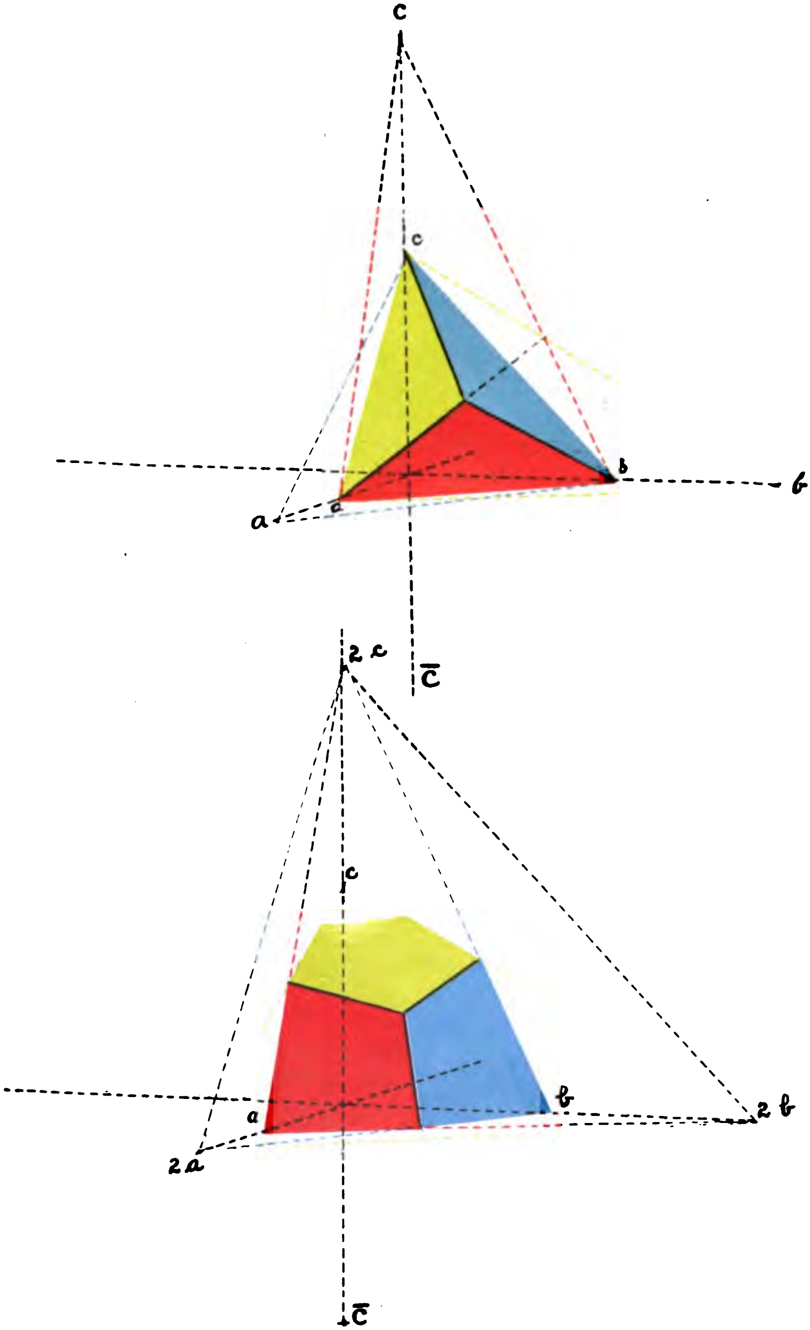


FIG. 5.—Completed octahedron

The diamond, like some other minerals, is symmetrically built. It has the same molecular structure in all directions. Light, heat, and electricity travel through it with the same ease and rapidity in the direction of all three of the axes, and the corrosive action of solvents is the same in all parts. Its axes are of the same value and interchangeable, and hence a numeral like 1 may be substituted for the letters a, b, and c and the ratio $\frac{a}{1}:\frac{b}{1}:\frac{c}{1}$ then becomes $\frac{1}{1}:\frac{1}{1}:\frac{1}{1}$. This cleared of fractions yields 1:1:1. The numbers in this ratio, 1:1:1, constitute the "parameters" of the octahedral plane, since they define the position of the plane. The parameter of another plane might be 1:2:2 or 2:1:2, etc.

The plane which has the parameter 1:2:2 represents a ratio $\frac{1}{2}:\frac{1}{1}:\frac{1}{1}$ and its symbol is (211) (Fig. 6). Since each of the three axes are equal, we can apply the 2 to each axis in turn and hence obtain three planes in every octant.

PLATE II



Construction of right-hand upper octant of a trisoctahedron above, and of a trapezohedron below.

Parameters	Ratios	Symbols
1:2:2	$\frac{1}{2}:\frac{1}{1}:\frac{1}{1}$	(211)
2:1:2	$\frac{1}{1}:\frac{1}{2}:\frac{1}{1}$	(121)
2:2:1	$\frac{1}{1}:\frac{1}{1}:\frac{1}{2}$	(112)

To construct these three planes in the right-hand upper octant (Plate II, lower diagram) measure off unit's distance on *a* and draw a line (red) cutting *b* at twice unit's distance, one cutting *c* at twice unit's distance, and one connecting the ends of *b* and *c*. Then from unit's distance on *b* draw lines (blue) cutting *a* and *c* at twice unit's distance, and connect the ends. Finally, beginning at unit's distance on *c* draw lines (green) cutting *a* and *b* at twice unit's distance and connect the ends. These lines will determine the position of planes which will intersect each other so as to form three trapezoids in the octant. When the same plan is followed for the other octants there results a trapezohedron (Figs. 6 and 7).

FIG. 6.—Model of trapezohedron

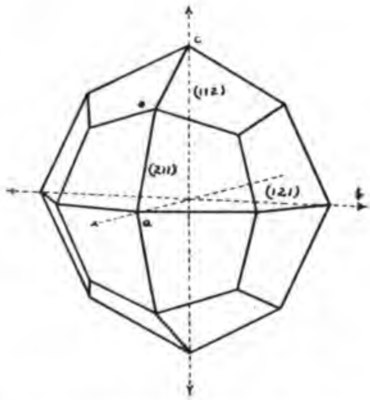


FIG. 7.—Completed trapezohedron

Having constructed figures with the symbol (111) and (211), the next in order will be one with the symbol (221) (Fig. 8). Its ratio will be $\frac{a}{2}:\frac{b}{2}:\frac{c}{1}$ and its parameter 1:1:2. Just as in the case of the trapezohedron, the numerals may be applied to each of the axes in turn. Thus writing the parameters, ratios, and symbols for the right-hand upper octant we obtain the following:

Parameters	Ratios	Symbols
1:1:2	$\frac{1}{2}:\frac{1}{2}:\frac{1}{1}$	(221)
2:1:1	$\frac{1}{1}:\frac{1}{2}:\frac{1}{2}$	(122)
1:2:1	$\frac{1}{2}:\frac{1}{1}:\frac{1}{2}$	(212)

Draw a line (red) cutting *a* and *b* at unit's distance and *c* at twice unit's distance (Plate II, upper diagram). From unit's distance on *b* draw lines (blue) cutting *a* at twice unit's distance and *c* at unit's distance. From unit's distance on *c* draw lines (green) cutting *a* at unit's and *b* at twice unit's distance. These lines determine the position of planes which intersect within the octant so as to produce triangles. The resulting planes are called trisoctahedral planes and the figure produced by continuing the process in each octant is called the trisoctahedron (Figs. 8 and 9).

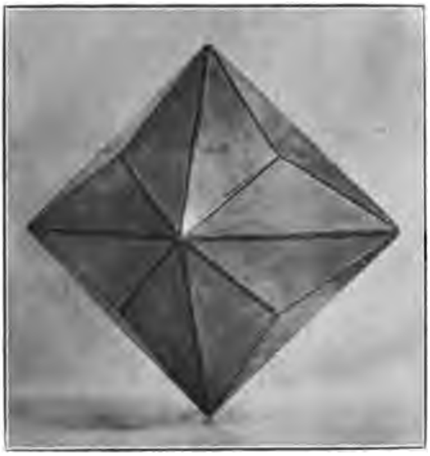


FIG. 8—Model of trisoctahedron

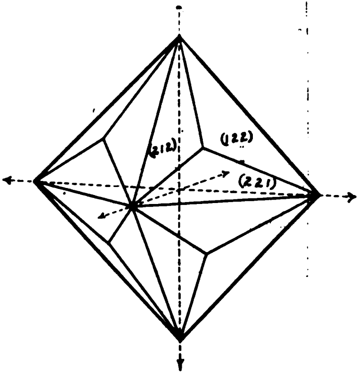
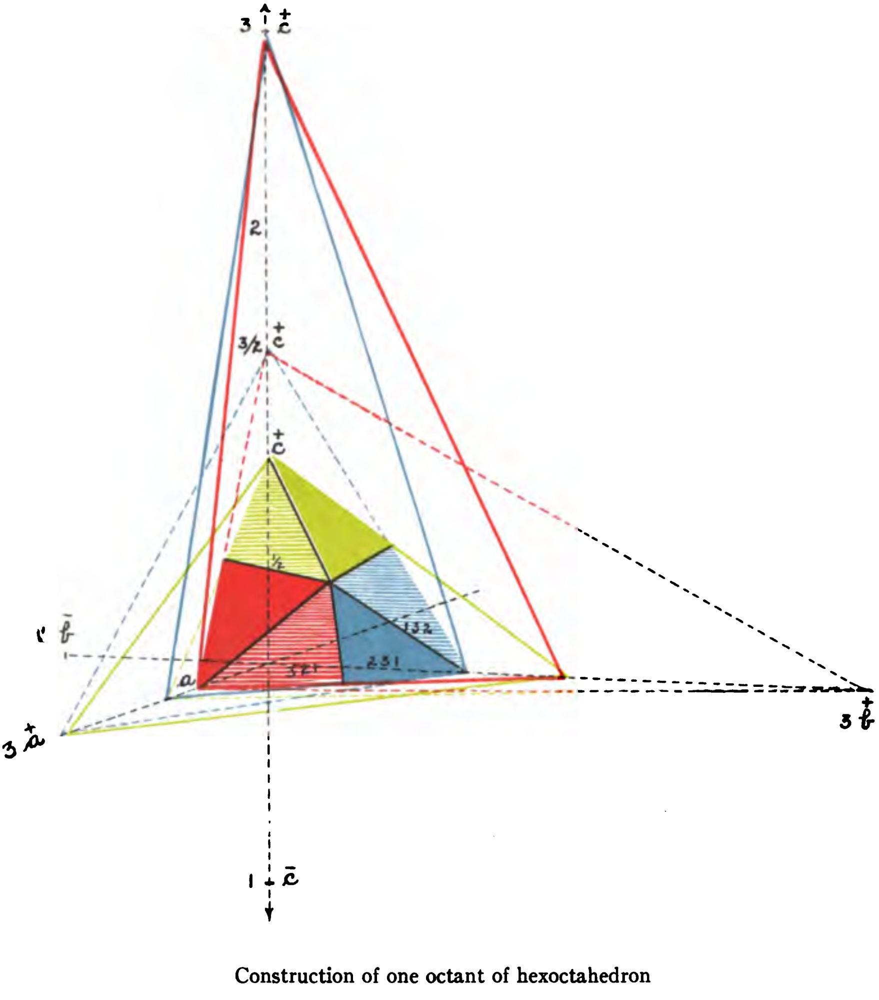


FIG. 9.—Trisoctahedron completed

PLATE III



Construction of one octant of hexoctahedron

The next form in point of complexity is one whose planes intersect each axis at different distances (Fig. 10). For example, its parameter might be $1:\frac{3}{2}:3$; its ratio then would be $\frac{1}{3}:\frac{1}{2}:\frac{1}{1}$, and its symbol (321). Since each number in the parameter is different, each of the three axes would be intersected at two points different from unity and there would result two planes at each corner of the octant, making six planes where the octahedron has but one.

Writing the parameters, ratios, and symbols as before, the following result:

Parameters	Ratios	Symbols
$1:\frac{3}{2}:3$	$\frac{1}{3}:\frac{1}{2}:\frac{1}{1}$	(321)
$\frac{3}{2}:1:3$	$\frac{1}{2}:\frac{1}{3}:\frac{1}{1}$	(231)
$3:1:\frac{3}{2}$	$\frac{1}{1}:\frac{1}{3}:\frac{1}{2}$	(132)
$3:\frac{3}{2}:1$	$\frac{1}{1}:\frac{1}{2}:\frac{1}{3}$	(123)
$\frac{3}{2}:3:1$	$\frac{1}{2}:\frac{1}{1}:\frac{1}{3}$	(213)
$1:3:\frac{3}{2}$	$\frac{1}{3}:\frac{1}{1}:\frac{1}{2}$	(312)

Proceed in the construction as was done with the octahedron, trapezohedron, and trisoctahedron. To construct, begin at unit's distance on *a* (Plate III) and draw a line (red) cutting *b* at three halves unit's distance and one cutting *c* at three times unit's distance. Complete the triangle by joining $\frac{3}{2}b$ and $3c$. Begin at unit's distance on *b* and draw a line (blue) cutting *a* at three halves unit's distance and one cutting *c* at three times unit's distance. Join $\frac{3}{2}a$ and $3c$. Again from unit's distance on *b* draw other lines (blue dotted) cutting *a* at three times unit's distance and *c* at three halves. Join the ends. Continue the construction from *c* (with green) and *a* (with red dotted) as indicated and the six planes of the octant will be produced. They are called the hexoctahedral planes. The same operation repeated in each octant produces a hexoctahedron (Figs. 10 and 11).

The faces above described are those most characteristic of the diamond, but usually faces of any one form do not make up the whole crystal. Sometimes planes of one form predominate and small faces of another modify the corners. Often two crystals will interpenetrate, each crystal having only half of its faces developed. If the right-hand upper octant and every alternate octant of the octahedron should grow to the exclusion of the other faces, a tetrahedron

FIG. 10.—Model of hexoctahedron

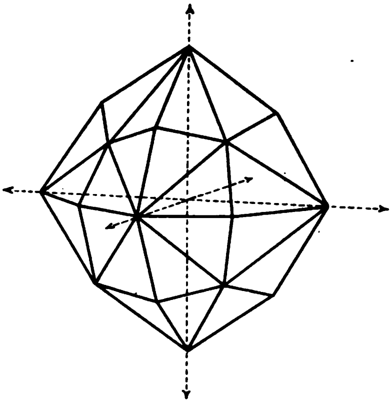


FIG. 11.—Hexoctahedron completed

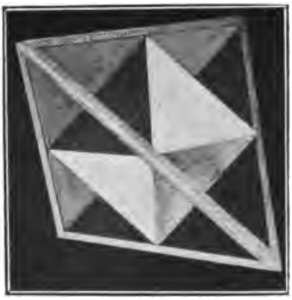


FIG. 12.—Growth of unshaded planes of the wooden octahedron produce the glass tetrahedron covering it.

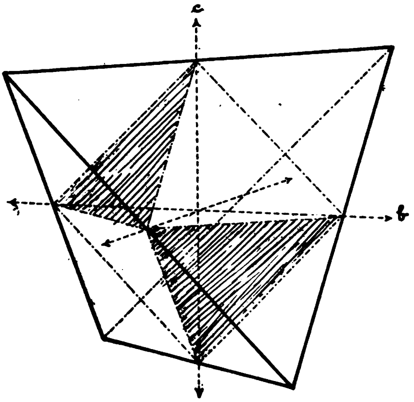


FIG. 13.—Right-handed tetrahedron

(Figs. 12 and 13) would result. If the left-hand upper octant and each alternate octant were developed, a left-handed or negative tetrahedron would be produced (Figs. 14 and 15).

Fig. 14.—Wooden octahedron inclosed by glass tetrahedron.

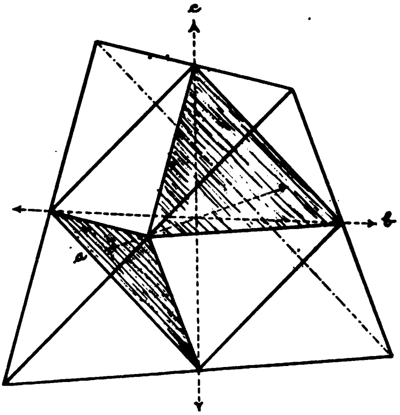


Fig. 15.—Left-handed tetrahedron

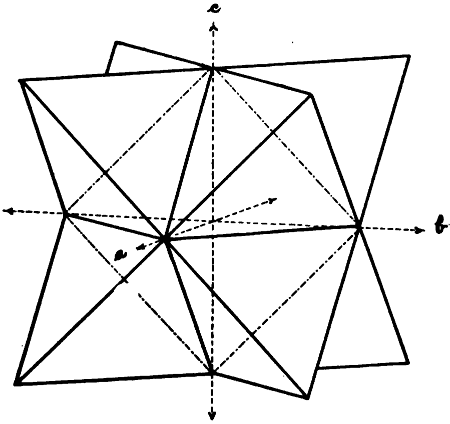


Fig. 16.—Interpenetrating supplementary tetrahedrons (tetrahedral twins).

When two supplementary tetrahedrons interpenetrate, the form represented in Figure 16 results. It is called an interpenetrating tetrahedral twin. Where an octahedron would have sharp edges, these tetrahedral twins have re-entrant angles.

Now if the projecting corners of each tetrahedron were truncated by the faces of the other tetrahedron, a form resembling an octahedron would result, but the re-entrant angles, instead of the characteristic edges, would reveal its true structure. This is a very common occurrence in the diamond (Fig. 17).

Just as with the octahedron, so also with the trapezohedron, trisoctahedron, or the hexoctahedron, a portion only of the faces might be developed. If the right-hand upper octant and every alternate octant of a hexoctahedron were produced at the expense of their neighbors, a right-handed hexatetrahedron would result (Figs. 18 and 19).

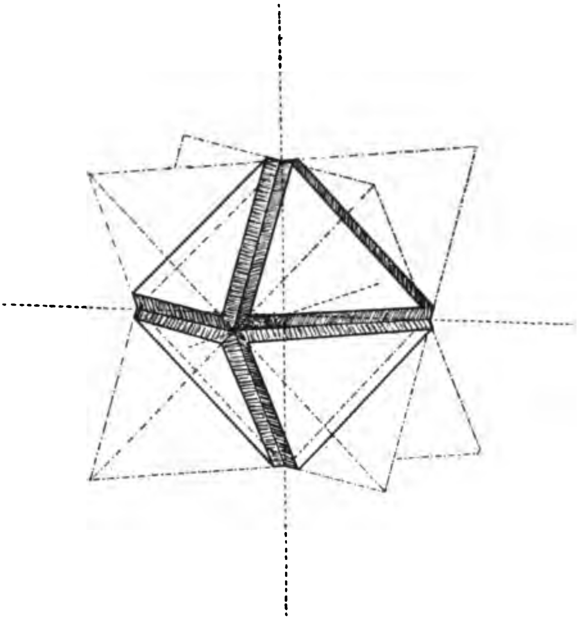


FIG. 17.—Tetrahedral twin with corners truncated

A left-handed or negative hexatetrahedron would be produced if the left-hand upper and every alternate octant were developed at the expense of their neighbors. A right-handed and a left-handed hexatetrahedron interpenetrating and having the corners truncated by tetrahedral planes give rise to one of the most characteristic forms of the diamond (Fig. 20).

Upon taking up a diamond, one first notices the prevailing octahedral form, but closer inspection reveals the re-entering angles, and in these angles the slightly inclined hexatetrahedral planes may be recognized.

Another form of twinning in the diamond is that which results when an octahedron is cut through the middle by a plane parallel to an octahedral face and one-half of the octahedron is turned 90° (as shown in Figs. 21 and 22). Diamonds of this sort are called "suture" stones by diamond dealers and by crystallographers "spinel twins," since they are even more commonly found among specimens of the mineral named spinel.

All of the above forms—the octahedron, the trapezohedron, trisoctahedron, hexoctahedron, tetrahedron, and hexatetrahedron—agree in this, that they are symmetrical in the same directions. If any of these forms were divided parallel to these directions, one-half would be just like the other.

FIG. 18.—Model of right-handed hexatetrahedron.

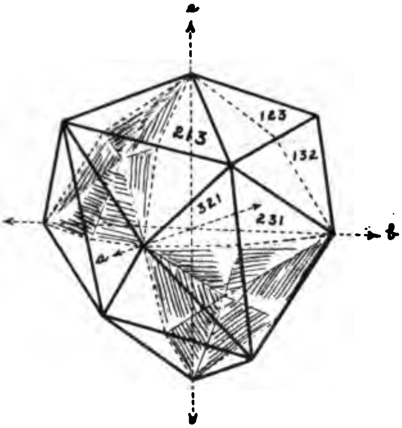


FIG. 19.—Construction of hexatetrahedron.

These directions are: first, parallel to any one of the three crystallographic axes, *a*, *b*, and *c* (Fig. 23); second, parallel to any one of the four axes perpendicular to the octahedral planes; third (Fig. 24), parallel to the six planes which would pass through the edges of a cube. Since this symmetry is best represented in a mineral called tetrahedrite, it is named the tetrahedrite class of symmetry.

By the above study we have become acquainted with facts in regard to the crystallography of the diamond and, more than that, with facts which are needed to understand the forms of a hundred other minerals as well. All of these minerals agree in this, namely, that the molecules which compose them arrange themselves similarly along three lines of equal length at right angles to each other, the *a*, *b*, and *c* axes. Hence these minerals are placed together in one of the six great groups in which all minerals are classified—the group known as the Regular System.

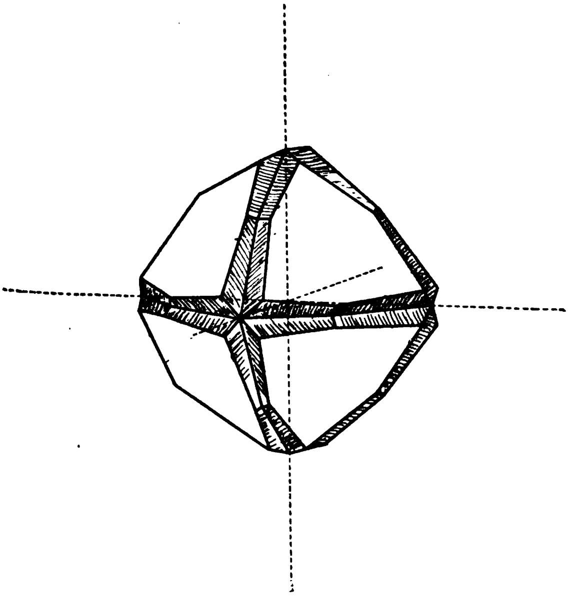


FIG. 20.—Interpenetrating truncated tetrahedrons beveled by hexatetrahedrons

As wood has certain directions in which it readily splits and contrary to which it breaks in an irregular manner, so the diamond has a direction in which it readily splits or "cleaves," namely, parallel to the octahedral planes. By taking advantage of the cleavage, diamond cutters are more readily able to fashion the gem into the desired shape. Cleavage is so easily obtained that it is difficult to break or "fracture" the diamond. When it is broken and not cleaved or split, the fractured surfaces are pitted or rounded like a shell. Consequently the fracture is said to be conchoidal.

Contrary to popular report, the diamond is brittle and easily shattered. Many valuable gems have been destroyed by the finders, who failed to recognize the difference between hardness and tenacity. For centuries it has been a tradition that if a diamond were laid upon an anvil and struck by a hammer, both anvil and hammer would fly to pieces before the diamond was broken. Pliny said that the only way to "subdue" a diamond is to "soften it in warm goat's blood"! Although the diamond is brittle, it is the hardest of minerals.

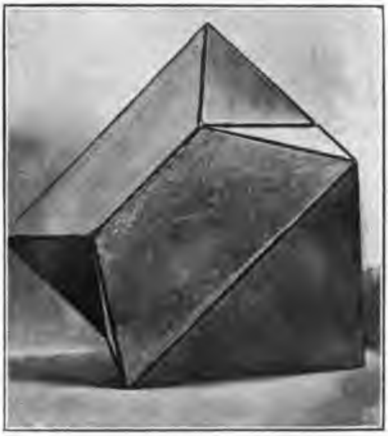


FIG. 21.—"Spinel twin" model. Twinning plane (111).

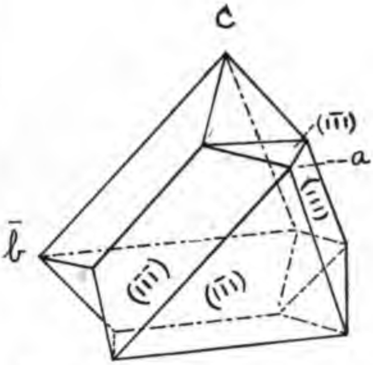


FIG. 22.—Drawing of spinel twin

Scale of Hardness

1. Talc
2. Gypsum
3. Calcite
4. Fluorite
5. Apatite
6. Orthoclase
7. Quartz
8. Topaz
9. Corundum
10. Diamond

To measure the hardness of minerals a scale has been arranged which consists of ten minerals so chosen that, beginning with the softest, each succeeding mineral is hard enough to scratch the one before it in the scale. Talc, which is the softest, is given as No. 1 in this list, and diamond as No. 10. The finger-nail can scratch any mineral below 3, and a knife-blade any below 6.

Specific Gravity of

1. Glass 2.5
2. Quartz 2.6
3. Phenacite 2.9
4. Topaz 3.5

When the weight of the diamond is compared with that of an equal volume of water, the diamond is found to be three and one-half times as heavy as water, i.e., its specific gravity is 3.5. It is much heavier than glass (sp. gr. about 2.5), which is most commonly employed to imitate it, or quartz (sp. gr. 2.6), the most abundant mineral that resembles diamond, or phenacite, "the deceiver" (sp. gr. = 3), which is sometimes worn to represent the more valuable gem.

The diamond shows color from two causes: first, because of actual coloring materials in it; and second, because it divides a ray of entering light into the colors of the spectrum. The coloring matter is usually some metallic oxide which does not change when heated. Sometimes the coloring matter is organic material which does fade when heated or held in sunlight. Many shades are seen—red, yellow, green, blue, indigo, brown. Yellow and brown are the most common among African diamonds. Brown may deepen into black, as in the opaque "carbons." Green is not so common. Blue and red are the rarest, and when these colors are pure, the diamond exhibiting them is the most valuable gem in the world. About half of all diamonds found are white or colorless. The color or "fire" which they then show is due to the fact that a ray of light which enters at an angle is refracted or turned very markedly from its course and is divided into rays of different wavelengths. The result obtained by dividing the angle which the entering light makes with a perpendicular erected to the surface of the mineral (called the angle of incidence, *i* in Fig. 25) by the angle which the ray makes with the perpendicular prolonged after it has entered the mineral (called the angle of refraction, *r* in the figure) is called the index of refraction. Thus

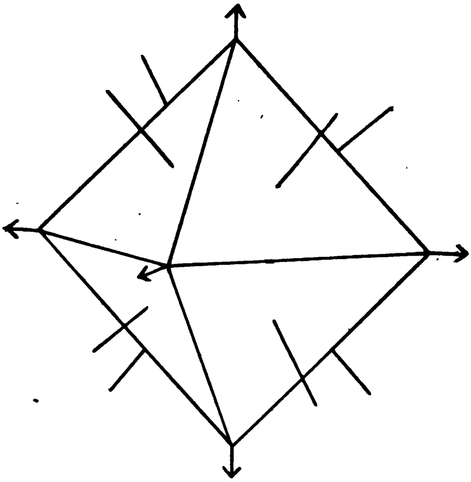


FIG. 23.—Two kinds of axes of symmetry

$$n = \frac{\sin i}{\sin r}.$$

The index of refraction *n* has a different value according to the kind of light used. For blue light in the diamond it is 2.465; for red, 2.402. That is, a blue ray is turned farther from a straight line than is a red ray. Now the difference between these indexes, 0.063, is called the dispersion. Both the refraction and dispersion of diamonds are high in comparison to the refraction and dispersion of other minerals. Because of its high refraction the diamond is unusually brilliant. It is said to show "life." Because of its high dispersion it has a remarkably vivid play of colors or "fire."

Mean Refractive Index of	
Ice	1.31
Salt	1.54
Quartz	1.55
Topaz	1.62
Glass	1.80
Cinnabar	3.02

Dispersion of	
Fluorite	.006
Quartz	.025
Diamond	.063

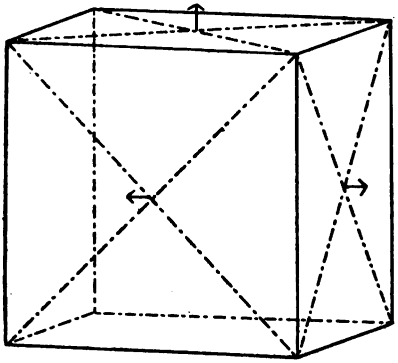


FIG. 24.—Dotted lines show direction of planes of symmetry in cube.

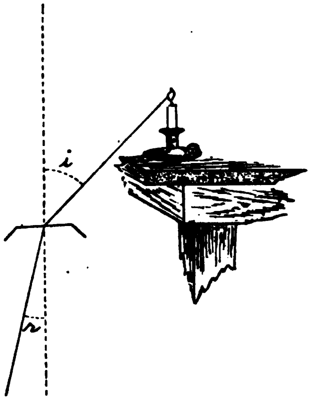


FIG. 25.—Angles of incidence and refraction.

Some diamonds which have a bluish tinge after being held in the sunlight emit light in the dark, i.e., become phosphorescent. Many phosphoresce after being rubbed on wood or while being subjected to an electric discharge in a vacuum or while exposed to radium emanations. Positive electricity is developed in the diamond by friction.

The diamond is worthy of its place as the leading gem, not only because of its hardness, brilliancy, and beauty of color, but also because of its permanency in the presence of corrosive gases and liquids. The air and moisture do not affect it. Ordinary acids cannot dissolve it. A solvent composed of sulphuric acid and potassium bichromate acts upon it slowly. At a high temperature (900°C.) in an oxygen flame, the diamond burns to carbon dioxide just as pure charcoal does, and sometimes leaves an extremely light ash that retains the original crystal shape and consists of iron, calcium, magnesium, and silicon which were present as impurities.

Though used as a gem for many hundreds of years, it is only within comparatively recent times that cutting of the diamond has been resorted to to enhance its beauty. Cutting and polishing are accomplished by the use of diamond dust imbedded in a tin disc or an iron plate.

Besides its use as a cutting tool, in its less well-crystallized forms it is extensively used to make drills. The diamond drill is one of the most useful implements invented for piercing rock in the search for valuable ores. The drills are made from the forms of diamond called bort and carbonado. Bort has radial fibrous structure, curved drusy surface, and is dark in color. Carbonado is somewhat compact, altogether without cleavage, slightly porous, black like charcoal, and somewhat harder than ordinary diamond. It is valuable for drills.

Diamonds have been found in nearly every part of the globe, yet for some cause or other in quantities worth mentioning only in regions less than 30° from the equator. A line following their most abundant occurrence would begin in southeastern Australia and extend eastward to South America; there, dividing into two branches, would pass in one branch north of the equator to British Guiana, and in the other, south to Bahia in Brazil. The northern branch extended would finally reach India, most prolific of ancient localities, and the southern branch would reach South Africa at Kimberley, the most productive of modern regions.

In India diamonds were first found and prized as gems. Most of the famous historical gems came from there. That field is now exhausted. The New South Wales fields yield about sixty thousand dollars' worth a year, British Guiana twice that amount, and Brazil five times that amount, while South Africa so far surpasses these regions as to make them hardly worth mentioning. It easily produces twenty-five million dollars' worth annually.

In India, Australia, South America, and also in a few localities in the Urals, and in Wisconsin, Michigan, Illinois, etc., diamonds have been found in sands and gravels in which they were imbedded when the original rock containing them was broken up and transported by glaciers or flowing streams.

In the Kimberley region, however, they occur in a greenish-blue igneous rock called ***kimberlite***, a sample of which is shown in Case 1.

The kimberlite occupies crater-like basins, sometimes nearly half a mile in diameter and of unknown depth, in the Triassic rocks of that region.

In Arkansas kimberlite has been found and has yielded a few diamonds.

Meteorites often contain minute diamonds.

Glass models of diamonds of unusual size and value, several of which have been long known and owned by kings and other celebrities, are shown in Case 1. No diamond is more famous than the Kohinoor. It weighs 106 carats and is valued at more than half a million dollars. It was found in India six hundred years ago (1304 A.D.) and for centuries was fought for or purchased by various rulers. It is now exhibited among the English crown jewels in London.

The Regent, which weighs 136 carats and is valued at six hundred thousand dollars, has had a most eventful history from the time when it was found in India by a slave, stolen from him by a sailor, bought and sold at ever-increasing price, till it came to sparkle in the hilt of Napoleon's sword, and finally, as one of the gems of the French Republic, was placed where it could ever after be inspected by all who cared to see it in the priceless collections of the Louvre, Paris.

The next is the Orloff, 193 carats, valued at half a million dollars, shaped so as to fit in the eye socket of an idol in India, from which it was stolen by a French soldier, finally purchased by Prince Orloff who sold it to Catherine II of Russia; and when last heard of it was in the Winter Palace, Petrograd.

Still larger is the Jubilee, 239 carats, valued at two million dollars, found in South Africa in 1895, and now in England.

The largest diamond ever found was the Cullinan (Plate I), named after the discoverer of the Premier Diamond Mine, South Africa. It was picked up in a shallow pit in that mine in January, 1905, by a foreman, who was given ten thousand dollars for his good fortune in recognizing it. It weighed uncut 3,025¾ carats, or about one and one-quarter pounds, and was valued at three million dollars. The Transvaal Republic donated it to King Edward VII of England, who, it was hoped, would place it unaltered in a museum to show for all time the largest diamond ever found. But the king had it cut into eleven brilliants—four of which are yet larger than any others known. Many diamonds smaller than those mentioned above are interesting because of their history.

The South Star, the largest diamond found in Brazil (in 1853) weighs 125 carats, is valued at four hundred thousand dollars, and is now owned by a prince in Baroda, India.

The Shah of Persia, 86 carats, now in Petrograd, has the shape of a four-sided prism with inclined ends.

No diamond has had a more varied history than the Sancy. It was found in India and, after being in the possession of Charles the Bold, who lost it on a battlefield, then among the jewels of the French Count De Sancy, then of Queen Elizabeth, then of Louis XIV, then of the King of Spain, and then of a Russian Prince Demidoff, has again been taken back to India by a native prince.

All of the above-named are beautiful white stones. There are some colored ones greatly prized, as, for example, the yellow Florentine and the blue Hope diamond. The Florentine, found in India, is now among the Austrian state jewels, after having been owned by Charles the Bold, Pope Julius, and the Empress of Austria. The Hope diamond is the most famous of all colored stones. It is of a vivid blue. It has been owned by wealthy and titled people in Italy, France, and England, and now is in the possession of a family in Washington, D.C.

SUMMARY

Diamond.—C. Regular; tetrahedrite class of symmetry: (111), (321); supplementary twins of tetrahedrons and contact twins on (111). Cleavage parallel (111) perfect; brittle; fracture conchoidal.

Hardness = 10; gravity = 3.52.

Colorless, yellow, brown, purple, red, blue; luster, greasy; transparent; refraction very strong. $n = 2.417$; dispersion very strong = 0.063.

Infusible; soluble in sulphuric acid and potassium bichromate.

Australia, South America, South Africa.

Graphite

Graphite (γράφειν, "to write"), another form of pure carbon, though not abundant in Illinois, is scattered in flakes through gneisses and other rocks which have been strewn over the state. It is a mineral so useful in many of our activities that it could not be spared. What, for example, would the people of the state do without lead pencils, lampblack, stove polish, graphite paints, and lubricants? The specimens on exhibit came from New Jersey, Ottawa, Canada, and Ceylon, of which localities the last has yielded the greatest quantities of the finest quality.

While the diamond is very pronounced in its shape, graphite is a mineral of weak molecular attraction. Its external form is not marked and, since it is opaque and cannot be studied under the microscope, there is even some doubt as to what its system of crystallization really is, although it is classified as hexagonal.

Usually it occurs in leafy or scaly flakes disseminated in rocks that originally were like limestone but have been changed by heat into marble or into other metamorphic rocks. Often it is segregated into compact, granular, or earthy masses forming veins in gneisses and schists.

While diamond is the hardest of substances, there is no mineral softer than pure graphite; while diamond is transparent and of light color, graphite is opaque and black; while diamond is a non-conductor of electricity, graphite is a good conductor. These differences are probably due to different arrangement of the atoms in the molecule, the graphite molecule containing three atoms, while that of the diamond contains nine.

Graphite is greasy to the touch, flexible, 1 in hardness, 2 in specific gravity, infusible, and insoluble.

Its specific heat is similar to that of the diamond. By specific heat is meant the heat required to raise one gram of a substance through one degree Centigrade. Taking as the unit the amount of heat required to raise one gram of water one degree in temperature, graphite requires only .12 and diamond .18 as much.

In the electric arc, diamond can be converted into graphite or graphite to diamond by varying the conditions.

Graphite is chiefly used for pencils, stove polish, paint, crucibles, and lubricants. In early days only the purest graphite could be employed for "lead pencils" since the "leads" were cut out of the solid material. Now material containing much foreign matter is pulverized and washed to free it from impurities, mixed with clay, and burned. The amount of clay used and the heat employed determine the degree of hardness of the pencil. Graphite is a valuable paint where heat is to be resisted. For the same reason—because of its extreme infusibility, and for its reducing action, i.e., its tendency to keep oxygen away from molten metals—it is employed for crucibles. As a lubricant it is useful for heavy machinery or wherever heat would destroy other lubricants. All of these uses are well illustrated in the graphite case.

SUMMARY

Graphite.—C. Hexagonal (?); in plates, scales, masses. Cleavage basal, perfect; flexible.

Hardness=1; gravity=2; black; streak gray; luster, metallic.

Ceylon, Siberia, Canada, Mexico.

Sulphur

One of the most interesting sights in one of America's most charming parks—the Yellowstone National—is a group of hills, the highest of which rises a few hundred feet above the surrounding country and is called "Sulphur Mountain." It is composed of siliceous and calcareous material mingled with vast quantities of sulphur. From the yellowish-gray mass here and there sulphurous vapors arise, and in many places sulphur springs burst forth and run in rivulets down the side of the hill, leaving behind a yellowish-white trail. In many places on the hill the sulphur is quite pure, earthy in character, and yellowish-gray in color. The cavities from which fumes are escaping are often lined with deposits of pure yellow sulphur that hang in clustered crystalline masses and have been formed by the sublimation of sulphurous vapors.

Sublimation deposits characteristic of volcanic regions do not furnish fine crystals such as may be obtained from Sicily, where in the marly limestones hot waters laden with sulphur in solution have deposited their burden under favorable conditions and produced large crystals. Samples of sulphur from the Yellowstone and from Sicily are shown. Illinois occurrences are limited to whitish masses remaining from decomposition of iron sulphide or calcium sulphate.

The structure of the sulphur crystal differs from that of a diamond, since sulphur has three well-defined directions in which light, heat, electricity, and various chemical reagents act with different ease and rapidity. Hence a sulphur crystal is represented by three axes of different lengths, which cross each other at right angles. These axes characterize the Orthorhombic System. In the regular system we found all axes equal; in the orthorhombic they are all unequal. The vertical axis *c* may be greater or less than the lateral axis *b*. Of the two lateral axes, the longer is always chosen as the *b* axis and the shorter as *a*.


FIG. 26.—Model of orthorhombic bipyramid

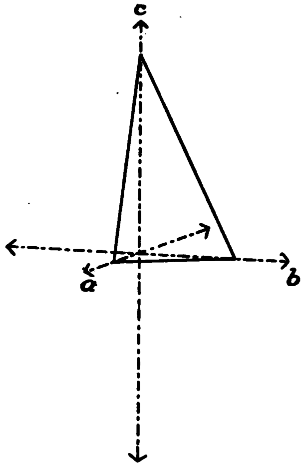


FIG. 27.—Orthorhombic pyramidal plane and axes.

Since these axes represent different lengths and values, they cannot be interchanged as they were in the regular system. Upon them three different kinds of planes may be constructed: first, those which intersect all the axes; second, those which intersect two axes and are parallel to the third; and third, those which intersect one axis and are parallel to two.

1. Planes which intersect three axes are called pyramid planes. They correspond to the octahedral planes of the regular system. When they intersect all three axes at unit's distance, the typical bipyramid results (Fig. 26). Figure 27 shows the construction of the pyramidal plane.

If the *c* axis is intercepted at one-third unit's distance, as is often the case with some planes that are found on sulphur, an obtuse bipyramid is produced (Fig. 28).

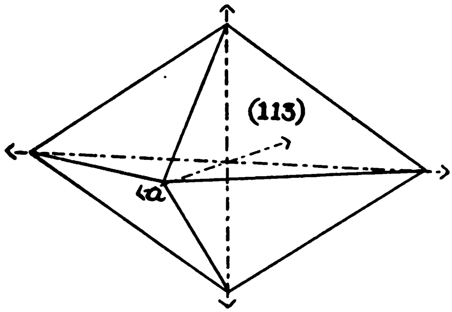


FIG. 28.—Obtuse bipyramid (113) characteristic of sulphur.

2. Besides pyramid planes occur the so-called dome planes (from *domus*, "house," since they are like a roof). They intersect two axes and are parallel to one of the lateral axes (Figs. 29–32). The plane which is parallel to the short axis is the brachydome, i.e., the short dome (Figs. 29 and 30). That one parallel to the long axis is called the macrodome, i.e., the long dome (Figs. 31 and 32). The domes do not produce closed figures unless united with each other or with some other planes. In Figures 29 and 31 they are closed by planes called pinacoids.

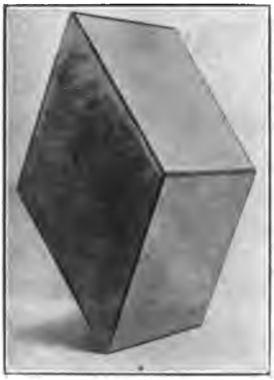


FIG. 29.—Model of brachydomes and macropincacoids.

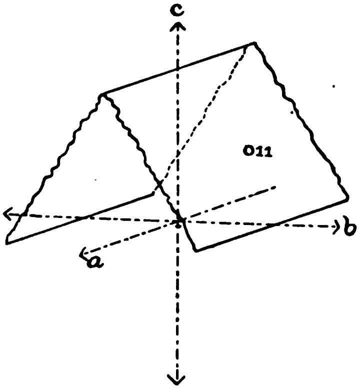


FIG. 30.—Upper brachydome planes (011).

Prism planes (Fig. 33), like domes, are parallel to one axis; but it is always the *c* axis to which a prism is parallel. The symbol of the prism may be (110) or (210), etc.

3. The third kind of planes consists of those parallel to two axes and intercepting one axis. They are called pinacoids (from πίνακος, "plane") (Figs. 34 and 35).

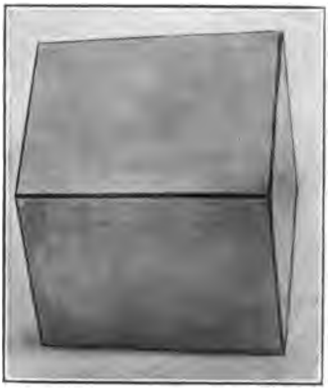


FIG. 31.—Model of macrodomes and brachypinacoids.

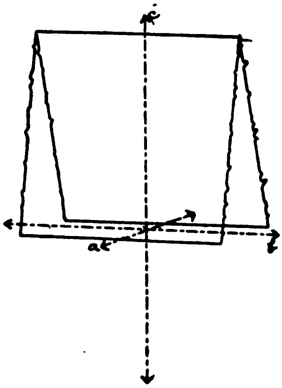


FIG. 32.—Upper macrodomes (101)

The basal pinacoid, or base, is parallel to *a* and *b* and intercepts *c* (001).

The brachypinacoid (short pinacoid) is parallel to the *c* and to the shorter of the two lateral axes, the *a*, but intercepts the *b* (010). The macropinacoid (long pinacoid) is parallel to *c* and to the longer of the lateral axes, but intercepts the *a* (100).

Figure 36 shows a combination of prism (110), brachypinacoid (010), and brachydome (011).

Pyramids, domes, prisms, and pinacoids complete the list of holohedral forms in the orthorhombic system.

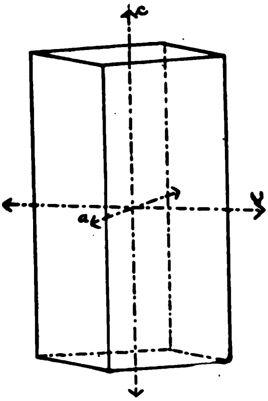


FIG. 33.—Prism (110) and basal (001) planes.

If the right-hand upper octant of a pyramid and each alternate octant were developed at the expense of their neighbors, a right-handed bisphenoid would be produced (Fig. 37). A left-handed or negative bisphenoid would result if the left-hand upper octant and alternate octants grew at the expense of their neighbors.

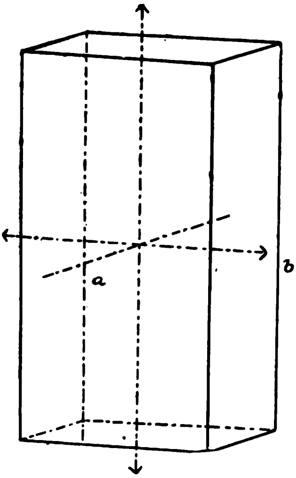


FIG. 34.—Base, macropinacoid, and brachypinacoid.

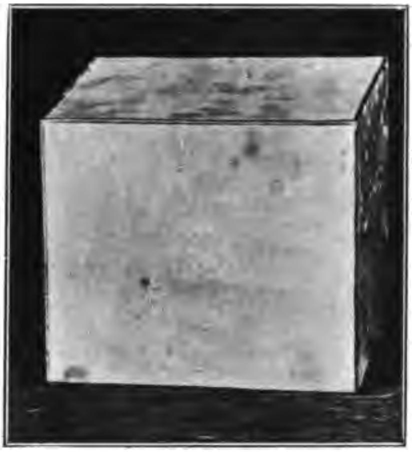


FIG. 35.—Model showing base, macro- and brachypinacoid.

FIG. 36.—Model of prism (110), brachypinacoid (010), and brachydome (011).

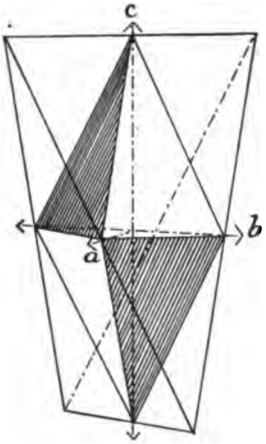


FIG. 37.—Right-handed sphenoid (111).

In sulphur these bisphenoids (111) are commonly united and modified by basal (001), dome (011), and obtuse pyramid planes (113) (Figs. 38 and 39).

In Figure 39 the left-handed sphenoid predominates while the right-handed appears as a very small plane. In Figure 38 they are of nearly equal size, but an edge instead of a corner where the *a* and *b* axes are intersected shows that the prevailing form is not a bipyramid but rather two bisphenoids.

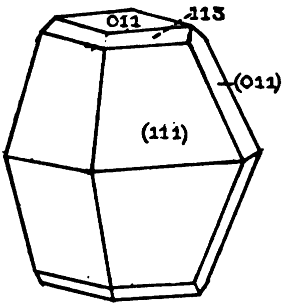


FIG. 38.—Sulphur, usual habit

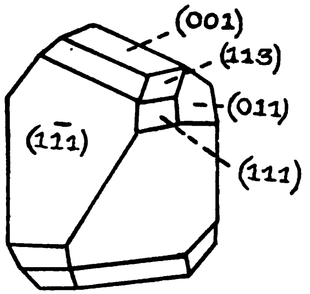


FIG. 39.—Sulphur, sphenoidal habit

Study of the sulphur crystal has shown that if the *b* axis is taken as unity, the *a* axis is .8 and the *c* is 1.9. Therefore to construct the various planes write parameters, ratios, and symbols as before.

		Parameters	Ratios	Symbols
Ordinary bipyramid	(Fig. 28)	.8:1:1.9	$\frac{.8}{1}:\frac{1}{1}:\frac{1.9}{1}$	(111)
Obtuse bipyramid	(Fig. 30)	2.4:3:1.9	$\frac{.8}{1}:\frac{1}{1}:\frac{1.9}{3}$	(113)
Brachydome bipyramid	(Fig. 32)	∞:1:1.9	$\frac{.8}{0}:\frac{1}{1}:\frac{1.9}{1}$	(011)
Macrodome bipyramid	(Fig. 34)	.8:∞:1.9	$\frac{.8}{1}:\frac{1}{0}:\frac{1.9}{1}$	(101)
Prism bipyramid	(Fig. 35)	.8:1:∞	$\frac{.8}{1}:\frac{1}{1}:\frac{1.9}{0}$	(110)

Similarly for the pinacoids.

If melted sulphur is quickly cooled, the molecules do not have opportunity to arrange themselves and the resulting mass is without definite form. It is said to be amorphous. If it is slowly cooled, crystals are formed similar to those occurring in nature but differing in this respect, that they slant downward parallel to the *a* axis, so that the front angle between the *c* and *a* axis, β, is greater than 90° (Fig. 40). The basal plane, being parallel to the lateral axes, slants forward. The crystals cannot be classed in the orthorhombic system but are in the monoclinic. (Monoclinic means having one inclination.) After a time, however, these monoclinic crystals become dull and fall to pieces, since their molecules tend to arrange themselves in the more stable form of the orthorhombic crystal. Orthorhombic crystals can be obtained artificially by allowing sulphur to crystallize from solution in carbon disulphide.

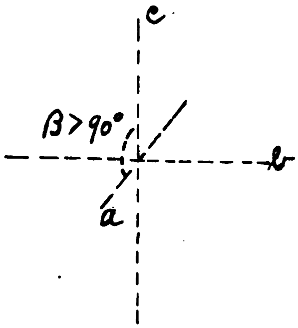


FIG. 40.—Axes of a monoclinic crystal.

Sulphur cleaves very imperfectly, parallel to the base (001) and to the prism (110). It is brittle and shows conchoidal surfaces when broken. Hardness=2; gravity=2; luster, greasy, resinous, adamantine. It allows light to pass through imperfectly, i.e., it is translucent. Its average angle of refraction is $n=2.04$. Since the density of its molecules varies in different directions, a ray of entering light is divided into two rays. These rays vibrate at right angles to each other and are differently refracted. The dispersion or difference between the angle of greatest and least refraction is 0.29.

The heat conductivity is so low that the warmth of the hand is enough to cause a sulphur crystal to crackle, as may be noticed when a crystal is held near the ear. Sulphur becomes electric by friction; volatilizes easily, forming sulphur dioxide; is insoluble in acids.

Hundreds of thousands of tons are mined in Sicily annually. Spain, France, and Germany produce smaller amounts. Louisiana, Texas, Nevada, and Utah are the chief source of the domestic supply. In 1916 the first two states supplied 98 per cent of the sulphur obtained in the United States.

SUMMARY

Sulphur.—S. Orthorhombic; symmetry holoaxial (sulphur class): (111), (113), (011), (101), (001).

Cleavage very imperfect (001), (110); brittle; fracture conchoidal.

Hardness = 2; gravity = 2. Yellow, orange, white; luster resinous; translucent; refraction strong, $n = 2.04$; double refraction very strong, positive.

Fusible; insoluble in acid; soluble in carbon disulphide.

Sicily, Spain, France, Germany, Louisiana, Texas.

Arsenic

A small mass of native arsenic from Austria represents the usual appearance of this mineral. It somewhat resembles slag from a metal furnace or some kinds of lava, since it shows a rounded, twisted surface, like a bunch of grapes crowded together, and is dull lead gray or blackish on the surfaces which have long been exposed to the air. The fresh surfaces are tin white and show the short radiating needles which build up individual portions of the mass. It is brittle, less than 4 in hardness, and 5.7 in specific gravity.

Native arsenic furnishes but little of the arsenic used in medicine and the manufacturing arts.

SUMMARY

Arsenic.—As. Hexagonal. Cleavage (0001); botryoidal, reniform, massive; brittle, conchoidal.

Hardness = 3.5; gravity = 5.6. Silver white; tarnishes lead gray to black; streak white.

Volatilizes without fusing, tinges flame blue, yields dense white fumes; odor of garlic.

Colorado, Chile, Saxony, Austria.

Antimony and Bismuth

These two brittle metals are very similar in their occurrence, properties, and uses. They do not develop well-defined crystals, but are usually found in grains, incrustations, or aggregations of scales which form masses. Bismuth is sectile and is the softer of the two, being about 2 in the scale, while antimony is 3. Bismuth is the heavier of the two, having a specific gravity of 9, while that of antimony is 6. Bismuth is somewhat reddish in hue; antimony is tin white. Both are metallic in luster, soluble in nitric acid, easily fusible and volatile. Both are found in association with silver, iron, arsenic, sulphur, and quartz. One hunting for these minerals should examine crystalline rocks.

The localities most noteworthy on account of specimens of antimony and bismuth are Saxony, Bohemia, and Japan. Many of the ores of precious metals in our western states contain these metals.

Antimony and bismuth are used in medicine and for the manufacture of alloys for type metal, babbitt metal, and other metals of low fusing-point.

SUMMARY

Antimony.—Sb. Hexagonal; symmetry dihexagonal alternating (calcite class). Cleavage parallel (0001) perfect, parallel $-\frac{1}{2}R$ fair; brittle; fracture uneven.

Hardness$=3.5$; gravity$=6.6$. Tin white; luster metallic; opaque.
Easily fusible, volatile; oxidizes in nitric acid.
Germany, France, Japan, Australia.

Bismuth.—Bi. Hexagonal; symmetry dihexagonal alternating (calcite class). Cleavage parallel (0001) perfect, parallel $-3R$ fair; sectile; fracture hackly.

Hardness$=2$; gravity$=9$. White with reddish tinge; luster metallic.
Easily fusible; volatilizes; soluble in nitric acid.
Germany, Bohemia, Colorado.

Gold

Probably there is more general interest in this mineral than in any other that is found in the earth's crust.

It was doubtless the first metal to be used by primitive man, since it is found in the beds of streams to which men would come for water and which were their highways from earliest times. Its glitter would attract the attention. When once its acquaintance was made, it would be easily recognized again, since it does not tarnish or rust, is very heavy, being 19 times as heavy as water, and so soft and malleable that it can be given various shapes and employed in many ways.

These qualities would lead men to use it long before they would notice or use the more abundant metals such as iron. It is found in the earliest tombs, such as those at Kertsch in the Crimea, in northern

Africa, and western Asia. Cloisonne work made in Egypt three or four thousand years ago shows skill in the use of gold.

The beauty of color, ease of working, weight and permanence of gold, render it a mineral of great value. But, however great its intrinsic worth, were it as common as quartz, for example, its value would be decreased.

Thus is it over all the earth
That which we call the fairest
And prize for its surpassing worth
Is always rarest.

Iron is heaped in mountain piles
And gluts the laggard forges,
But gold flakes gleam in dim defiles
And narrow gorges.

The snowy marble flecks the land
In heaped and rounded ledges,
While diamonds hide beneath the sand
Their starry edges.[1]

Gold is found usually in quartz veins, in pyrite and other sulphides, or in sands and gravels.

In quartz it occurs as fine threads or thicker wires that run singly or are bunched into mossy or treelike masses (arborescent). Sometimes it is in scales or grains isolated at times or packed together so as to form lenses or nuggets. Wiry and granular masses alike are rounded, twisted, and so distorted as to give little suggestion of crystal faces. However, an exposed end of one of these grains or threads, one which has had opportunity to develop in a cavity uncrowded by quartz or some other mineral, may show crystal faces clearly enough developed to permit of study and to make possible the

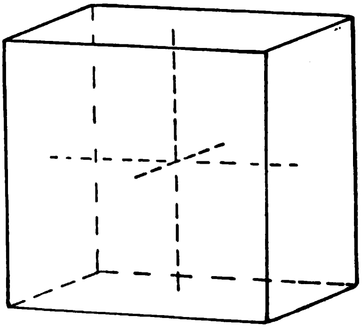


FIG. 41.—Cube

---

[1] J. G. Holland, "Bitter Sweet."

conclusion that the structure of gold agrees with that of the diamond, the molecules being so arranged as to place it in the regular system.

Besides the octahedron (111), two other forms appear, namely, the cube (100) (Fig. 41) and the four-sided cube (tetrahexahedron, 210) (Figs. 42 and 43). To construct the cube, write the notation as before. Since the axes are interchangeable, six planes will be produced. The parameters of the front, right side, and top are as follows:

Parameters	Ratios	Symbols
$1:\infty:\infty$	$\frac{1}{1}:\frac{1}{0}:\frac{1}{0}$	(100)
$\infty:1:\infty$	$\frac{1}{0}:\frac{1}{1}:\frac{1}{0}$	(010)
$\infty:\infty:1$	$\frac{1}{1}:\frac{1}{0}:\frac{1}{1}$	(001)

A cube with four faces in each cubic face (Figs. 42 and 43) results when one of the three axes is intersected at twice unit's distance, for example.

Parameters	Ratios	Symbols
$1:2:\infty$	$\frac{1}{2}:\frac{1}{1}:\frac{1}{0}$	(210)
$2:1:\infty$	$\frac{1}{1}:\frac{1}{2}:\frac{1}{0}$	(120)
$\infty:1:2$	$\frac{1}{0}:\frac{1}{2}:\frac{1}{1}$	(021)
$\infty:2:1$	$\frac{1}{0}:\frac{1}{1}:\frac{1}{2}$	(012)
$1:\infty:2$	$\frac{1}{2}:\frac{1}{0}:\frac{1}{1}$	(201)
$2:\infty:1$	$\frac{1}{1}:\frac{1}{0}:\frac{1}{2}$	(102)

Gold crystals are usually small, distorted, and so grouped that to study and decipher them is a difficult matter. The gold contained in pyrites and metallic sulphides is so finely divided as to be invisible. It is mechanically included in the sulphides and not chemically united with the sulphur. In nearly every country in which gold is mined, it was first discovered in sands and gravels, and such deposits until within the last fifty years have been the chief source of the metal.

Like diamonds, gold has been able to withstand the friction to which it was subjected while being washed from the original ledge. Diamonds resisted the friction because of their hardness; gold because of its tenacity; both have endured because of their insolubility and slight affinity for oxygen. The condition of gold in alluvial deposits varies from dust of microscopic fineness to nuggets many pounds in size. In California a nugget weighing 161 pounds was found. The largest nuggets have been discovered in Australia, three weighing over 200 pounds having been found there. The largest of them, the "Welcome," weighed 248 pounds.

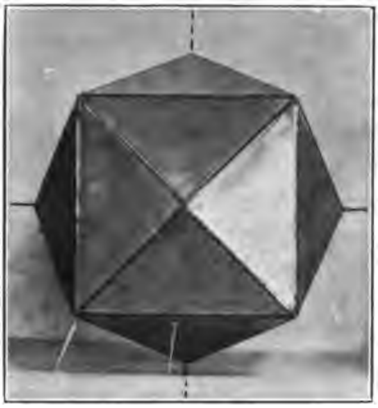


FIG. 42.—Tetrahexahedron model

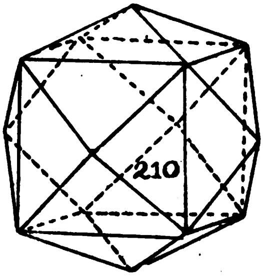


FIG. 43.—Construction of tetrahexahedron.

The origin of nuggets of such size has been a matter of much speculation, since no masses of similar size have been found in veins. It has been suggested that small particles carried downstream were welded together by the impact of water-tossed gravel until a large nugget was formed, or that the nuggets have grown by accretion of gold from some percolating solution. Polished and etched surfaces of nuggets, however, show crystalline structure. This would be wanting in welded gold, and there is an absence of the onion-like structure that would be expected if the gold were deposited by accretion from solution. Hence it may be concluded that the nuggets were originally in quartz veins and have been rounded in the downward journey from some high ledge to the resting-place in which they were discovered.

As to the origin of gold, nothing is known. The same may be said in regard to all elements. All that is known is something of the method of their transference and deposition. Light is shed on the subject by the fact that many fresh waters and all sea waters contain gold in appreciable quantities. There is nearly one grain of gold (five cents' worth) in every ton of ocean water. Then in all the oceans there is about seventy-five billion dollars' worth.

Gold in solution, possibly as a telluride, chloride, or cyanide, was carried by waters and deposited by them upon neutralization, cooling, or evaporation. Though the surfaces of gold crystals are rounded and often look as if melted, their appearance is not due to fusion but to their manner of crystallization. The origin of the gold is the same as the origin of the vein material inclosing it—quartz, fluorite, and calcite. All of these minerals are commonly deposited from aqueous solutions.

Gold melts at 1200° C. and forms such perfectly spherical globules that by microscopical measurements it is possible to estimate the amount of gold in a globule and hence to dispense with fine balances in assaying. Gold is soluble in aqua regia only (a combination of nitric [HNO_3] and hydrochloric [HCl] acids).

Sulphur and oxygen do not unite with gold, and hence it remains bright in nature or when worn as an ornament.

All gold contains silver in solid solution. As the amount of silver increases, the alloy becomes paler, lighter, and more liable to dissolve in nitric acid. Most Hungarian gold contains 30 per cent of silver, California gold 10 per cent, Australian gold (Mount Morgan, Queensland), reputed to be the purest, only .3 per cent.

Platinum, copper, and iron minerals, calcite, fluorite, quartz, feldspar, amphibole, and pyroxene, mica, garnet, and zircon, are the minerals most usually found with gold.

The rocks in which gold-bearing veins are found are igneous rocks such as granites, syenites, and porphyries; or metamorphic rocks such as gneisses and schists. The richest veins are usually at places of contact of different kinds of rock.

California, Nevada, Colorado, Montana, and South Dakota have been the chief producers of gold in this country since the discovery of the metal in California in 1848. The only gold found in Illinois is an occasional piece contained in some rock transported from northern regions by the glaciers of Pleistocene times. There are no deposits of commercial importance. In spite of this fact, the procession of people who hope to discover such deposits or think they have done so will never end. They bring to the museum iron sulphide (pyrite), decaying mica (vermiculite), and other minerals, confident that they have found valuable deposits of precious metal; and when disillusioned are dejected. At one time the United States, at another time South Africa, leads the world in gold production, while Australia ranks third.

Gold is a metal useful in all places where hardness and toughness are not desired but where insolubility, permanence in the air, beauty of color, softness, and ductility are sought. Since the earliest times it has been used for personal adornment and for ornaments for the home, the church, and the palace. It is universally favored as a medium of exchange.

SUMMARY

Gold.—Au. Regular; holosymmetric; distorted (111), (100), (210); fibers, plates, grains. Malleable; ductile; fracture hackly.

Hardness = 2.5; gravity = 19.3. Gold yellow, metallic, opaque.

Fusible at 1200° C.; soluble in aqua regia.

Western North and South America, South Africa, Australia.

Silver

Silver resembles gold in its mode of occurrence, crystal habit, and physical properties. Chemically it is not so stable as gold, being readily affected by acid fumes and liquids. It is rarely found in placer deposits, but occurs most commonly in wiry, mossy, flaky, or granular forms in veins.

Sometimes large pure masses are discovered. One of the most famous was an eight-hundred-pound mass found in Peru. Another from Kongsberg, Norway, weighing five hundred pounds, is preserved in Copenhagen.

Crystals of silver are usually so distorted that their form is difficult to decipher, but under favorable circumstances octahedrons (111), cubes (100), and tetrahexahedrons (210) can be distinguished.

Like gold, silver has no direction of easy separation (cleavage). When broken, the fractured surfaces are splintery. It is inferior to gold in its malleability and ductility, as it is possible only to beat leaves of it so thin that it requires one hundred thousand leaves to form a pile one inch in height, and one grain can be drawn out into four hundred feet of wire. Gold, however, can be beaten into leaves thin enough to require two hundred and eighty-two thousand leaves to form an inch-high pile, and one grain can be drawn into five hundred feet of wire.

Silver is unsurpassed as a conductor of electricity. Its conductivity is placed at 100 per cent, that of copper at 93 per cent, and platinum at 16 per cent.

One thousand degrees Centigrade of heat are required to melt it. When fused it can absorb twenty times its bulk of oxygen, which it gives off upon cooling, causing it to blossom into arborescent forms.

It is readily soluble in nitric acid. It unites with sulphur so easily that to keep silver bright is a very difficult task.

The chief source of the metal is not native silver but sulphides such as argentite, proustite, tetrahedrite, etc., minerals which will be described later.

The association, occurrence, and localities of silver are nearly identical with those of gold.

The United States has for many years been one of the principal producers, as well as the chief consumer, of silver.

It is estimated that the ocean contains over two million tons of silver worth more than $38,000,000,000.

Silver is used extensively for coinage, for making household articles, for photographic purposes, and in various other ways.

SUMMARY

Silver.—Ag. Regular, holosymmetric; (100), (210), (111); twinned on (111). Threads, wires, plates, grains, masses. Malleable; ductile; fracture hackly.

Hardness = 2.5; gravity = 10.5. White, metallic, opaque.

Fusible at 1050° C.; soluble in nitric acid.

Cordilleran states in both North and South America, Australia, Germany.

Copper

Copper is similar in its physical characteristics, association, and occurrence to the two minerals just described, but is more abundant.

eave
leav
leav
to

nd
and

t it.
h it
ms.
so

es
ill

PLATE IV

Dendritic copper from Calumet and Hecla mining region, Michigan.

In the rare crystal faces discernible, possibly the tetrahexahedron (210) and dodecahedron (110) (Fig. 44) are more common than they are in gold and silver. The dodecahedron (110) can be constructed from the following parameter (Fig. 45):

Parameter	Ratios	Symbols
$1:1:\infty$	$\frac{1}{1}:\frac{1}{1}:\frac{1}{0}$	(110)

Wiry and arborescent forms are common. Masses of remarkable size have been found. One of the largest was 45 feet long and weighed 420 tons. It was found in the "Minnesota Mine" in Michigan. That region has produced more pure copper than any other in the world, The copper is disseminated in breccias, conglomerates, and basalts, or is collected in veins of calcite, fluorite, analcite, and quartz which penetrate the basalt. Often a cavity is filled partly with copper and partly with silver. If these metals had been deposited from a fused mass, they would have been united in an alloy rather than standing side by side. Evidently they were formed from a solution, and the more difficultly soluble silver was first deposited and later the copper.

FIG. 44.—Model of a dodecahedron

Copper is redder than gold and much more soluble. It is one of the most useful of metals, being used for electrical purposes and for many domestic and commercial articles.

The United States has produced about three times as much copper as the rest of the world together. Arizona, Montana, and Michigan are the leading states in production. In the two former the ores are chiefly sulphides and carbonates; in Michigan, native copper.

Glacial drift from the north has brought nuggets of copper, some of them weighing more than 50 pounds, and scattered them widely over Illinois. One (No. 695) found in the drift in Peoria County weighs 18$\frac{5}{8}$ pounds. A hole was cut through it by the finder so that it could be used on a rope to close a gate. No. 693 from Macon County weighs 17$\frac{6}{8}$ pounds and is covered with the fine green deposit with which time paints old copper domes of churches and palaces. This deposit is formed when carbon, oxygen, and water unite with copper to produce the copper carbonate called malachite. No. 3383 is an irregular nugget (11$\frac{7}{8}$ pounds) which shows the scratches made by the rocks over which the nugget was pushed while frozen in a glacier. No. 259, a small nugget from Jersey County, was found farthest south of any specimen in the collection.

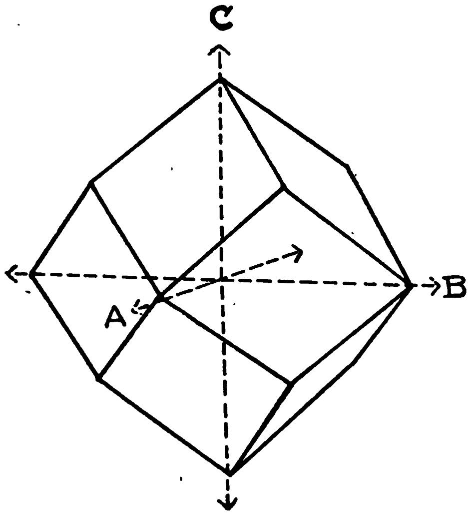


Fig. 45.—Construction of a dodecahedron

Summary

Copper.—Cu. Regular, holosymmetric; elongated (210); twinned on (111); threads, wires, masses. Malleable; ductile; fracture hackly.

Hardness = 2.5; gravity = 8.9. Copper red, metallic, opaque.

Fusible at 1100° C., soluble in nitric acid.

Michigan, Arizona, New Mexico.

Mercury

Mercury is the only element which is liquid at ordinary temperature. It solidifies at −40° C. and in so doing crystallizes in the regular system. It unites so readily with sulphur that it is rarely found uncombined with that element. Cinnabar, HgS, is the chief source of the metal.

Mercury is used in making medicine, in "silvering" mirrors, and in the manufacture of toys, but chiefly as a means of collecting finely divided gold in placer mining and in the free milling process.

About the same time that gold was discovered in California, fortunately quicksilver was found at New Almaden, some fifty miles south of San Francisco.

The United States is at present the leading country in the production of cinnabar, from which mercury is obtained. The famous old Spanish localities now take second rank. Nature has not provided any deposits of mercury in Illinois. Nor do we need it as much as do some other states.

SUMMARY

Mercury.—Hg. Liquid, amorphous; at −40° C. Regular.
Gravity = 15. White, metallic, opaque.
Volatilizes, sublimes.
California, Spain.

Platinum

Platinum is a steel-gray, metallic, moderately hard, exceedingly heavy mineral occurring in small flat grains in alluvial deposits. The world's supply has been obtained practically from the Ural Mountains alone. If its appearance and characteristics were more widely known among prospectors, other localities might be added to the list of producers.

Because of its peculiar utility and rarity, platinum is at present unsurpassed in commercial value by any metal. Its especial usefulness depends upon its resistance to heat. Over 2000° C. are required to melt it. This, in addition to its insolubility, makes it serviceable for dental purposes, for crucibles, wire, and foil to be used in chemical laboratories and manufacturing plants and for electrical purposes. The attempt to find some metal which will take the place of platinum has been unsuccessful.

The United States uses about half of all the platinum produced in the whole world.

The crystal form of platinum, being similar to that of gold, silver, and copper, presents nothing new for consideration.

Platinum is very finely disseminated in gravels derived from serpentine and syenite, and large placers may be expected only in very old land areas which have been subjected to protracted degradation. The Ural Mountains furnish such conditions.

Small percentages of platinum are often obtained from sulphides of antimony, arsenic and copper, and in chromite. The placers of the Ural Mountains, Columbia, and California contain, associated with platinum, other minerals of high specific gravity such as gold, cassiterite, magnetite, hematite, chromite, and rutile.

SUMMARY

Platinum.—Pt. Regular; holosymmetric; grains and nuggets. Malleable; ductile; fracture hackly.

Hardness = 4.5; gravity = 19; chemically pure, 21. Steel gray.

Infusible; soluble in nitro-hydrochloric acid (aqua regia).

Nijni Taguilsk (Urals); Columbia, South Africa, Canada, Wyoming, California.

Iron

Iron so readily unites with oxygen, sulphur, and other elements that it rarely occurs native. Consequently, while minerals containing iron are numerous and abundant, pure iron is rare. Yet it is one of the most interesting of minerals because of its origin. Some of it is terrestrial and some meteoric in origin.

Terrestrial iron is found as small imbedded particles in basalt, peridotite, and serpentine—three kinds of dark rocks abundant in many mountain regions—and in deposits derived from the disintegration of these rocks. Gold and platinum are usually associated with terrestrial iron.

At several places on the west coast of Greenland, especially at Disco Island, large masses of iron occur which are regarded as originating from deep-seated portions of the earth, since the basalts of the region contain scattered grains and globules of iron.

Meteoric iron illustrates the fact that the science of mineralogy is concerned not only with this earth but with the universe as well.

Until within the last one hundred years the idea prevailed that meteorites were portions of this earth which had been thrown out of volcanoes with such velocity as to reach great heights and then to fall back with enormous speed. But as the composition of meteorites became known and the circumstances connected with their fall were investigated, students of the subject were convinced that they are fragments of other heavenly bodies—the dust of the universe.

PLATE V

Mukerop meteorite, one-sixth natural size. Fell in Amalia-Goamus, West Africa. Section mentioned on page 44 was cut from the center of this mass.

Myriads of them enter the earth's atmosphere. At night they are seen to flash in the heavens when they are ignited by the friction generated in their fall through the earth's atmosphere. Many enter the atmosphere at such an angle that they leave it without touching the earth; many are totally consumed as they fall; some reach the earth's surface as cosmic dust, as grains, or even as masses many tons in weight. In 1894 at Cape York, in the northern part of Greenland, a mass weighing 36 tons was found and three years later brought by R. E. Peary to New York City. It was called by the Eskimos "Ahnighito" or "The Tent."

Occasionally a meteorite has been seen as it fell and has been picked up while still warm. Those which have been observed in the air and then found are called "falls." Their number is less than the so-called "finds," which are not seen to fall but are simply picked up. Several hundred "falls" and "finds" have been collected and described.

A meteorite entering the atmosphere may have an astonishingly high velocity—something like 45 miles a second—but because of the resistance of the air be reduced in velocity and strike the earth's surface with small force. Meteoric stones fell upon the ice at Hessle, Sweden, and rebounded without either breaking the ice or being themselves shattered. The heat generated by the friction with the air fuses the surface of the meteorite, especially on the front side, and causes the melted material to flow back in waves, making a kind of "varnish." Meteorites are usually pitted with thumblike impressions. Since the heating is sudden, the surface may be fused while the interior is still cold. The unequal expansion causes them to explode with loud report and to scatter over wide territory.

According to constitution there are three kinds of meteorites: first, those consisting almost wholly of iron (siderites); second, those having a cellular matrix of iron in which stony matter is imbedded (siderolites); and third, those composed almost entirely or wholly of stony matter (aerolites).

Meteoric iron is massive, but its crystalline structure can be readily discerned when it is etched with diluted nitric acid, since triangular markings usually appear on the surface. They are due to the presence of nickel. The form and the widths of the bands depend upon the percentages of nickel present. The figures resulting are called Widmanstätten figures, after the man who first studied them.

The largest meteorite ever discovered in the United States and one of the most interesting is the Willamette iron. It was found 19 miles south of Portland, Oregon, in 1902. It weighs 15 tons and is now in the American Museum of Natural History.

Meteorites have been found in our neighboring states, Michigan, Indiana, Kentucky, Missouri, Iowa, and Wisconsin, but thus far not a single example has been reported in Illinois. All accounts of the finding of meteorites in this state have upon investigation proved to be untrue. There appears to be no reason why falls may not occur here at any time. If people are more observant, we may some time discover and preserve these messengers from the great waste spaces.

The largest meteorite exhibited in the collection (No. 4064) is a $\frac{7}{8}$-inch-thick section from 13 to 15 inches in diameter and weighing $13\frac{5}{8}$ pounds avoirdupois. It was cut from the Mukerop meteorite which fell in southwestern Africa (Plate V). The following also are shown: a dozen examples of the Canon Diablo, Arizona, meteorite (No. 3385); about fifty of the Holbrook, Arizona; one from Eddy County, New Mexico (Sacramento Mountains, No. 3384); Sheridan County, Kansas (Saline, No. 4106); Lyon County, Kansas (Admire, No. 4104); Phillips County, Kansas (Long Island, No. 4109); Iowa County, Iowa (Homestead, No. 4107, and Forest, No. 4108); Emmet County, Iowa (No. 1730); Bullitt County, Kentucky (Salt River, No. 4103); Kent County, Michigan (Grand Rapids, No. 4103); and state of Mexico, Mexico (Toluca, No. 4101).

Summary

Iron.—Fe. Nickel usually present. Regular; (111), (100); massive lamellar; cleavage parallel (100) perfect; malleable; fracture hackly.

Hardness=4.5; gravity=7.5. Gray to black, metallic, magnetic
Infusible; soluble in acid.

Greenland, and in meteorites of wide distribution.

LIST OF ELEMENTS AND THEIR ATOMIC WEIGHTS

Name	Combining Weight Oxygen = 16	Name	Combining Weight Oxygen = 16
Aluminium, Al	27	Mercury, Hg	200
Antimony, Sb	120	Molybdenum, Mo	96
Argon, Ar	39	Neodymium, Nd	144
Arsenic, As	75	Neon, Ne	20
Barium, Ba	137	Nickel, Ni	59
Beryllium, Be	9	Nitrogen, N	14
Bismuth, Bi	208	Osmium, Os	191
Boron, B	11	Oxygen, O	16
Bromine, Br	79	Palladium, Pd	107
Cadmium, Cd	112	Phosphorus, P	31
Caesium, Cs	132	Platinum, Pt	195
Calcium, Ca	40	Potassium, K	39
Carbon, C	12	Praeseodymium	141
Cerium, Ce	140	Radium, Ra	226
Chlorine, Cl	35	Rhodium, Rh	103
Chromium, Cr	52	Rubidium, Rb	85
Cobalt, Co	59	Ruthenium, Ru	102
Columbium, Cb	94	Samarium, Sm	150
Copper, Cu	63	Scandium, Sc	44
Dysprosium, Dy	162	Selenium, Se	79
Erbium, Er	167	Silicon, Si	28
Europium, Eu	152	Silver, Ag	108
Fluorine, F	19	Sodium, Na	23
Gadolinium, Gd	157	Strontium, Sr	88
Gallium, Ga	70	Sulphur, S	32
Germanium, Ge	72	Tantalum, Ta	181
Glucinum, Gl	9	Tellurium, Te	127
Gold, Au	197	Terbium, Tb	159
Helium, He	4	Thallium, Tl	204
Hydrogen, H	1	Thorium, Th	232
Indium, In	114	Thulium, Tu	168
Iodine, I	127	Tin, Sn	119
Iridium, Ir	193	Titanium, Ti	48
Iron, Fe	56	Tungsten, W	184
Krypton, Kr	83	Uranium, U	239
Lanthanum, La	139	Vanadium, V	51
Lead, Pb	207	Xenon, Xe	131
Lithium, Li	7	Ytterbium, Yt	172
Lutecium, Lu	174	Yttrium, Y	89
Magnesium, Mg	24	Zinc, Zn	65
Manganese, Mn	55	Zirconium, Zr	91

CLASS II. SULPHIDES

The next group of minerals which would naturally claim the attention of the visitor is that which embraces minerals consisting of a mixture of sulphur with some metal like antimony, molybdenum, lead, silver, copper, zinc, mercury, or iron.

From the twenty-five or more minerals in the group, thirteen are common; and while but eight of them are found in Illinois, all are used here and all are of interest, since they show marked properties.

They are stibnite, molybdenite, galena, argentite, chalcocite, sphalerite, cinnabar, pyrrhotite, erubescite, chalcopyrite, pyrite, marcasite, and arsenopyrite.

Stibnite

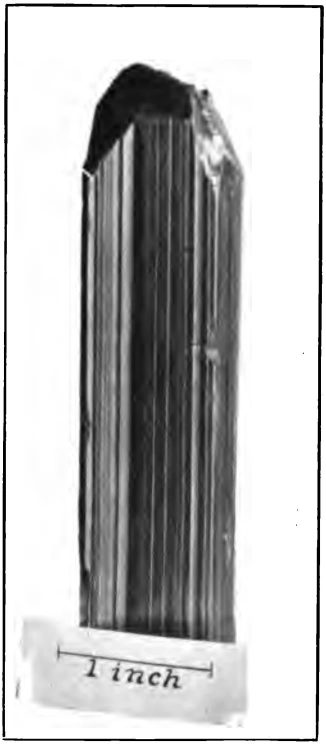
Stibnite, a sulphide of antimony (Sb_2S_3) is the chief source of the metal, antimony. Its crystals are often large and beautiful. They resemble sulphur crystals since their structure is different in three directions. The planes which are usually developed are prisms and pinacoids. Several pyramid planes are of common occurrence. The crystals are holohedral. Basal planes are wanting. The long needle-like crystals often terminate in a flat pyramid (113), as shown in Figure 46. The ratio of the axes $a:b:c$ is .99:1:1.01, differing thus but slightly from a mineral in the regular system.

Applying these values and using the parameter as usual, the following result:

Parameters	Ratios	Symbols
$2.97:3:1.01$	$\frac{.99}{1}:\frac{1}{1}:\frac{1.01}{3}$	(113)
$.99:1:\infty$	$\frac{.99}{1}:\frac{1}{1}:\frac{1.01}{0}$	(110)
$\infty:1:\infty$	$\frac{.99}{0}:\frac{1}{1}:\frac{1.01}{0}$	(010)

Some crystals of stibnite are of remarkable size and beauty. One of the finest specimens in any museum may be seen in the British Museum. It is a group of crystals eighteen inches long and terminated by lustrous pyramid faces. It came from the antimony mines

PLATE VI



a, Stibnite, Japan

b, Molybdenite from Aldfield, Pontiac County, Quebec, Canada.

at Shikoku, Japan, a locality which has furnished a larger number of remarkable specimens than any place in the world. Our largest specimen, No. 3784 (Plate VI *a*), comes from the same place. Other samples are from Portugal, Australia, and the western United States. Stibnite crystals are often twisted, curved, and warped. The most usual occurrence is that of massive forms with bladelike or fibrous structure.

The mineral cleaves easily parallel to the brachypinacoid, and shows nicks and horizontal lines at right angles to the *c* axis, indicating "glide planes" parallel to the base (001). These glide planes make it possible for the crystals to bend, and explain their curved and twisted form.

That the mineral is in the orthorhombic system can easily be illustrated by the difference in rapidity with which heat is transmitted in different directions. Senarmont's method is to coat a brachypinacoid plane with wax and touch it with the point of a hot wire. The wax is melted more rapidly in the direction of the *c* axis than in the direction of *a*. Consequently the resulting figure is an ellipse. Roentgen's method, similar in principle, is to breathe upon a face, touch it with the point of a hot wire, then sprinkle lycopodium powder upon it. When shaken, the powder drops from the mineral where it was dry. The form of the clean space is an ellipse with the long axis parallel to the *c* axis.

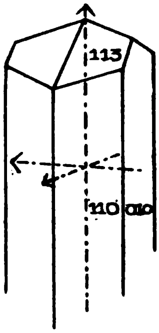


FIG. 46.—Stibnite crystal.

Stibnite is found with other sulphides (argentite, galena, sphalerite, cinnabar) and with barite and quartz in veins in granite and gneiss.

The ancients used stibnite as a pigment to darken eyebrows. Its chief use at present is as a source of antimony.

SUMMARY

Stibnite.—Sb_2S_3; Sb = 71.8 per cent, S = 28.2 per cent. Orthorhombic; (110), (111), (113), (010). Massive, bladed, fibrous, granular. Cleavage (010) perfect; glide planes (001); slightly pliable; fracture conchoidal.

Hardness = 2; gravity = 4.6. Steel gray; metallic; opaque.

Easily fusible (1 in the scale); volatilizes; soluble in hydrochloric acid.

Japan, Hungary, Australia, California.

Molybdenite

Molybdenite, the sulphide of molybdenum (MoS_2), is a soft metallic mineral, bluish lead gray in color. It occurs in six-sided (hexagonal) tabular crystals in quartz veins (Plate VI *b*). In softness, color, and form it closely resembles graphite but can be distinguished by the fact that the color is bluish and the mark left on paper (the "streak") is bluish, while the color and streak of graphite are lead gray. Molybdenite (gravity=4.7) is also more than twice as heavy as graphite.

Its crystals are often striated horizontally, taper toward the top because of the decrease in the diameter of its constituent lamellae, and show glide planes. Foliated, scaly, and granular particles sometimes are scattered through the containing quartz and at other times concentrated in the masses. With it are often found other sulphides such as pyrite and chalcopyrite. It has been deposited from solution in crystalline rocks, such as pegmatite granite, gneiss, and granular limestone.

The chief sources of supply in the United States recently have been California, Colorado, Montana, Maine, and Washington. None is found in Illinois.

Molybdenum compounds are used in coloring silk, leather, and porcelain blue. They have a limited use in chemical laboratories for the determination of phosphorus; in the manufacture of steel a fraction of a per cent of molybdenum hardens the steel and changes its coefficient of expansion.

SUMMARY

Molybdenite.—MoS_2; Mo=60 per cent, S=40 per cent. Hexagonal; plates, scales; cleavage parallel (0001). Flexible; sectile.

Hardness=1; gravity=4.7. Bluish gray; metallic; opaque; greasy. Infusible; soluble in nitric acid.

California, Colorado, Montana, Washington, Maine, Canada, and many European localities.

Galena

Because of its physical properties and its importance commercially, galena, the sulphide of lead (PbS), is an interesting mineral. It is found in great masses or disseminated in limestone, as in the Mississippi Valley region, and in veins in crystalline rock, as in the

Cordilleran region. In the Cordilleras the galena is usually argentiferous and consequently one of the chief sources of silver in this country. In the Mississippi Valley region it contains practically no silver but is associated with the zinc sulphide, sphalerite.

Galena is mined in many places in both hemispheres, but probably in no place more extensively than in Missouri and Idaho. In early days in the Mississippi Valley region the avocation of the farmers was often the quarrying of galena for lead from which to cast bullets in time of war and for making pewter ware in time of peace. Some galena is found in Pope and Hardin counties in Illinois in connection with the fluorite mined there, and some is produced in the northwestern portion of the state. Scattered crystals may be detected in the "Niagara" limestone at different places. The finest samples shown in the museum collection are from Jo Daviess County. No. 421 is a cube whose corners are truncated with octahedron planes. It measures over three inches each way and weighs 7⅛ pounds (Fig. 49). No. 3396 is another smaller cube, and No. 267 is a large mass which has been incrusted with iron sulphide (marcasite). Where the incrustation has broken off, the underlying galena may be seen. When one sees this pronounced crystallization he is impressed with the fact that when minerals have the opportunity they have a form as well defined as that of a flower.

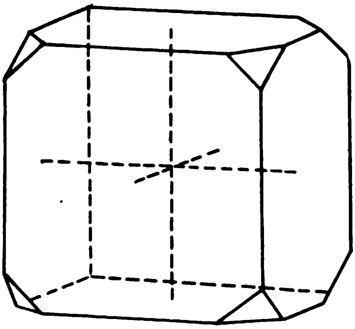


FIG. 47.—Cube truncated by octahedron.

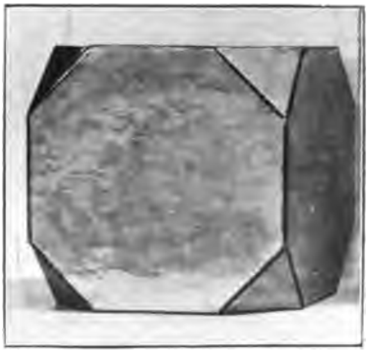


FIG. 48.—Model of a cube truncated by an octahedron.

Galena is soft, heavy, lead gray, metallic, and opaque. It crystallizes readily, so that even massive forms when cleaved show the structure, and well-formed crystals are very common. The usual habit is fine cubes with the corners truncated by octahedrons (Figs. 47 and 48). The octahedrons may be enlarged so as to almost displace the cube, or they may become so small as to disappear.

The cube faces are often formed by very flat four-faced cube planes (*hko*), *h* and *k* representing any two different numbers. If $h=4$ and $k=1$, the symbol is (410), a tetrahedron often met with.

Fig. 49.—Galena, Jo Daviess County, Illinois.

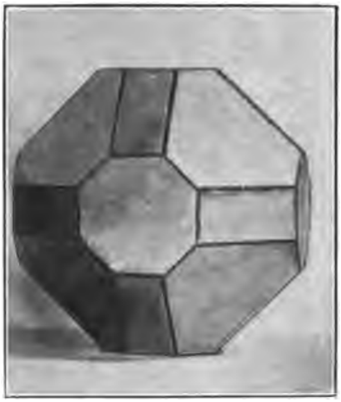


Fig. 50.—Model of planes appearing on galena.

Crystals often exhibit the dodecahedron (110) in combination with the cube and octahedron (Fig. 50).

Cleavage is so perfect that a single blow of a hammer will shatter a crystal into multitudes of little cubes whose faces may show striations parallel to the lower right-hand trisoctahedron (441) due to twining lamellae parallel to that plane (Fig. 51). Since glide planes can be produced in this direction by pressure, the striae may be due to that cause.

Galena which contains from 1 to 2 per cent of bismuth has octahedral cleavage. When heated enough to drive off the bismuth, the cleavage becomes cubic. Singularly, galena containing bismuth does not decrepitate when heated, as does ordinary galena, nor is there a change in its specific gravity. Further, with the change in crystalline structure, there is no decrepitation such as occurs in ordinary galena.

Galena usually contains small amounts of silver sulphide, and as the amount present increases, the galena loses its coarse cubic structure and becomes finely granular.

When covered with a layer of wax and touched with the point of a hot wire, the wax melts in a circle, showing that galena is in the regular system.

Argentite, sphalerite, chalcopyrite, pyrite, fluorite, quartz, calcite, and rhodochrosite accompany galena in limestones or in crystalline rocks.

Since galena furnishes the lead of the world, it is one of the most useful of minerals.

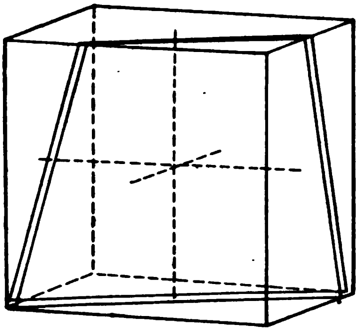


FIG. 51.—Twin lamellae in galena parallel to (44$\bar{1}$).

Lead is used in plumbing, in the manufacturing of paint, medicine, alloys, shot, etc.

SUMMARY

Galena.—PbS; Pb=86.6 per cent, S=13.4 per cent. Regular; holosymmetric; (100), (111), (110), (221). Cleavage (100) perfect; fracture even; nearly sectile.

Hardness=2.5; gravity=7.5. Lead gray; metallic; opaque.

Easily fusible, decrepitates; soluble in nitric acid.

Mississippi Valley, Cordilleran region.

Argentite

Argentite, the sulphide of silver (Ag_2S), is one of the chief sources of the metal. It closely resembles galena but does not occur in such distinct crystals. Usually it is in the form of dendritic, scaly, earthy, or granular masses. It does not cleave as readily as galena but is sectile. It is associated with the same minerals and is found in crystalline rocks such as are wont to contain gold, silver, and other precious minerals. The best crystal shown, No. 3822, was obtained at Guanajuato, Mexico.

SUMMARY

Argentite.—Ag_2S; Ag = 87.1 per cent, S = 12.9 per cent. Regular, holosymmetric; (100), (110). Cleaves imperfectly parallel (100), (110); sectile; fracture sub-conchoidal.

Hardness = 2.5; gravity = 7.3. Color and streak lead gray; metallic; opaque.

Melts readily; soluble in nitric acid.

In the mountain ranges in western North and South America, and in many European and Australian localities.

Chalcocite

In Arizona during 1918 nearly as much copper was produced as was obtained from Michigan, Montana, and Utah combined. The ore consists chiefly of chalcocite (Cu_2S), a mineral which is dark lead gray in color, metallic, and opaque, and occurs in granular or compact masses. It resembles argentite in general appearance, but is more brittle and is often tarnished blue or green when the addition of sulphur changes the chalcocite (Cu_2S) to covellite (CuS), or the addition of iron changes it into erubescite (Cu_3FeS_3). While chalcocite crystallizes in the orthorhombic system, well-formed crystals are rare. Since the angle between the prism planes (110) is 60°, chalcocite often looks as if it were a hexagonal mineral. When several crystals are twinned about the prism planes, the form is even more deceptive.

Chalcocite is found in connection with other sulphides at many localities in the Cordilleran range. No example has been reported in Illinois.

SUMMARY

Chalcocite.—Cu_2S; Cu = 79.8 per cent, S = 20.2 per cent. Orthorhombic; $a:b:c = 0.58:1:0.97$. Common planes (110), (001), (023), (113); twinned on (110), (032); cleavage imperfect (110); sectile; fracture conchoidal.

Hardness = 2.5; gravity = 5.7. Lead gray; streak black; metallic; opaque.

Easily fusible; soluble in nitric acid.

Cordilleran region, England, Germany.

Sphalerite

Many localities in which lead is abundant are also famous because of their great deposits of sphalerite (ZnS). The early German miners who were seeking lead were disappointed when they found sphalerite instead, and therefore called it *Blende* from *blenden*, "to deceive." "Sphalerite," from the Greek, has the same meaning.

Pure sphalerite has the color of resin. See the specimen from Spain (No. 3765). Usually it is dark because of impurities like iron, cadmium, manganese, tin, thallium, indium, and gallium that are often present in varying quantities. Some sphalerite contains as much as 20 per cent of iron. Miners call the dark varieties "Black Jack." See specimens from Colorado, Kansas, and Missouri. Gallium and indium were first discovered in sphalerite. Sphalerite occurs, as do most of the other sulphides, when igneous rocks such as granites, diabases, and porphyries are in contact with metamorphic rocks such as gneisses, schists, and granular limestones, especially where these rocks have been fissured and subsequently cemented by vein-forming materials. In the Mississippi Valley region, however, sphalerite usually is found in beds or is scattered through the limestone.

Well-crystallized specimens are seen to follow the laws of the regular system and to illustrate the same class of symmetry as that which is shown by the diamond, the "tetrahedrite class."

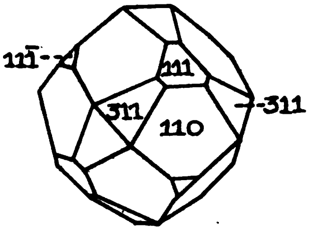


FIG. 52.—Sphalerite

Common forms such as that in Figure 52 are combinations of tetrahedrons (111), dodecahedrons (110), and trapezohedrons (311). The tetrahedrons are positive and negative, and upon the alternate octants only occur the planes which together would produce the hemihedral form called the three-faced tetrahedron (311) (Figs. 53 and 54). Supplementary tetrahedrons combined with cubes are characteristic (Fig. 55). The positive and negative tetrahedrons may be distinguished by the difference in their size, by their differing smoothness, by the different markings which their faces show when they are etched with dilute hydrochloric acid, and by a pyro-electric test. To make this test cut a plate parallel to a face of each of the two tetrahedrons in turn. Insulate, connect with an electroscope, and touch with the point of a heated wire. One tetrahedron will become positively electrified, and the other negatively.

Twin lamellae parallel to tetrahedral faces are common in the sphalerite of many localities.

Stibnite, galena, argentite, pyrite, marcasite, chalcopyrite, fluorite, quartz, calcite, and barite are the associates of sphalerite.

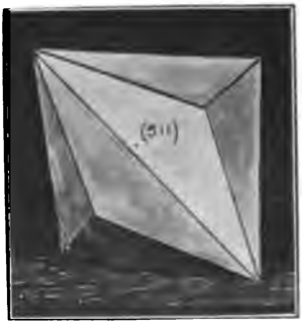


FIG. 53.—Model of a three-faced tetrahedron, a tristetrahedron.

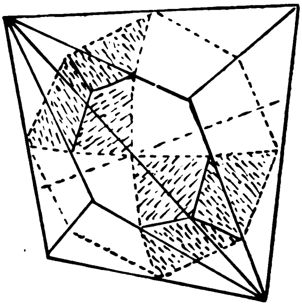


FIG. 54.—Construction of trigonal tristetrahedron.

FIG. 55.—Sphalerite

The region around Joplin, Missouri, has produced probably more sphalerite than has any other locality in the world, and Illinois is the leading state in zinc smelting from these ores. The museum collection contains also specimens from Alston Moor, England, and Kapnik, Hungary, two places famous for their many fine crystals.

Sphalerite is the most important source of zinc, and the metal obtained from it is used in galvanizing iron, in zinc plating, in paint manufacture, and in medicine.

SUMMARY

Sphalerite.—ZnS; $Zn = 67$ per cent, $S = 35$ per cent. Regular, tetrahedrite class; (111), (110), (311), (100). Cleavage perfect parallel (110); brittle; fracture conchoidal.

Hardness = 3.5; gravity = 4. Yellow, adamantine, translucent; refraction $n = 2.37$.

Fusible with difficulty; soluble in hydrochloric acid.

Kansas, Missouri, Illinois, Wisconsin, Colorado, Utah, Montana, Europe.

Cinnabar

Though mercury occurs sometimes uncombined in nature, the chief source of the metal is cinnabar (HgS). Cinnabar, a word used in India two thousand years ago, means "red resin" and is well applied, since the color of the mineral is bright red and the streak vermilion. See specimens No. 3401 and No. 3893. Impurities make it brown or slaty (No. 593). Crystals of cinnabar are rare. The mineral is notable for its refractive power, the ordinary ray (ω) being more strongly refracted than it is in diamond. $\omega=2.85$.

Further, a ray of light entering the crystal in almost any direction is divided into two rays which vibrate at right angles to each other. That is, it is "doubly refracted." One ray is called the ordinary (ω) and the other the extraordinary (ϵ). When the difference between them is great, the double refraction or "birefringence" is said to be strong. In cinnabar $\epsilon-\omega=0.35$.

Of late years more cinnabar has been produced in the United States than in any other country, and of this production the greater part is furnished by California. None is found in Illinois.

Summary

Cinnabar.—HgS; Hg=86.2 per cent, S=13.8 per cent. Hexagonal; "quartz class": (1010), (0001), rhombohedrons (1011); $c=1.145$. Cleavage good, parallel (1010); fracture uneven.

Hardness=2.5; gravity=8.2. Cochineal red; streak vermilion; luster, metallic, adamantine; translucent. Refraction very strong, $\omega=2.85$; birefringence, positive, very strong ($\epsilon-\omega=0.35$). Circular polarization very strong.

Volatile; soluble in nitric acid.

New Almaden, California; Spain; and south Russia.

Pyrrhotite

Pyrrhotite (πυρρός, "reddish") is a bronze-colored, magnetic iron sulphide, which occurs in massive forms and is often lamellar in structure.

Its crystallization is so imperfect as to leave doubt concerning its true nature, and, being opaque, its optical properties can shed no light on the question. However, its structure is probably such as characterizes the hexagonal system.

There is also doubt as to the chemical composition of pyrrhotite. Different formulae have been given to it, ranging from Fe_6S_7 to $Fe_{11}S_{12}$. The formulae all agree closely with the monosulphide FeS, troilite, which is a mineral not known on the earth but common in some meteorites.

Pyrrhotite is not so abundant as other iron sulphides. The iron which it contains cannot be separated from the sulphur without great difficulty. However, in some localities, as at Ducktown, Tennessee, immense quantities of sulphuric acid are made from it. Nickel and cobalt are often present in paying quantities, and the nickeliferous pyrrhotite of Pennsylvania, Canada, and Norway is an important source of those metals.

SUMMARY

Pyrrhotite.—$Fe_{11}S_{12}$; Fe = 56 to 61 per cent; S = 44 to 39 per cent. Hexagonal plates, masses. Brittle; fracture uneven.

Hardness = 4; gravity = 4.6. Bronze yellow; streak grayish black; metallic; opaque; magnetic.

Fusible; soluble in nitric acid.

Appalachian and Cordilleran systems; Europe.

Erubescite

Erubescite, the "blushing ore" (Cu_3FeS_3), owes its beauty to the ease with which it tarnishes. It is called also bornite, variegated copper, horseflesh ore, peacock ore. When freshly broken it has a coppery or bronzy color, but soon tarnishes to a vivid blue or purple. Its color is its most interesting characteristic.

Granular or compact masses are the most usual, but sometimes crystals in cubes can be distinguished. As is always the case, the crystals represent the purest condition.

Cornwall, England, South Africa, and some of the Cordilleran states furnish the best crystals and the most abundant supply of erubescite. Our best samples were obtained in Colorado (No. 3753) and New Mexico (No. 2195).

SUMMARY

Erubescite.—Cu_3FeS_3; Cu = 55.5 per cent, Fe = 16.4 per cent, S = 28.1 per cent. Regular; (100); twinned on (111); cleavage imperfect, parallel (111); slightly sectile; fracture sub-conchoidal.

Hardness = 3; gravity = 5. Pinchbeck brown, bronze, tarnished blue; streak grayish black; metallic; opaque.

Fusible; soluble in nitric acid.

With other copper ores in Colorado, Montana, South Africa.

Chalcopyrite

Very closely related to erubescite in chemical composition but much more pronounced in physical characteristics and commercial importance is chalcopyrite ($CuFeS_2$), i.e., copper pyrite, a name given by Henckel in 1725 when a difference between this and pyrite was for the first time noticed. Chalcopyrite and chalcocite are the chief sources of copper today.

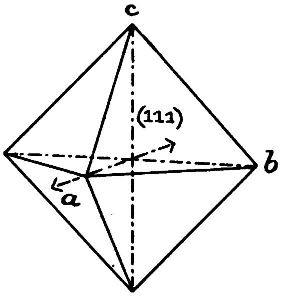


FIG. 56.—Acute primary bipyramid

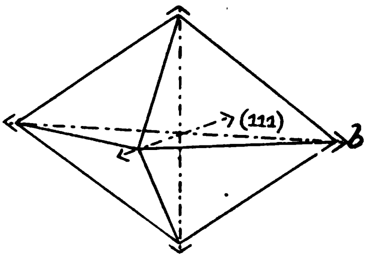


FIG. 57.—Obtuse primary bipyramid

Lustrous, clean-cut crystals of chalcopyrite are common, and were early studied by crystallographers who thought they were in the regular system until, in 1822, accurate measurements showed that the *c* axis is 0.985 when *a* and *b* are unity. Hence the crystals are in the Tetragonal System, that system in which the *c* axis is longer or shorter than the *a* and *b*, the *a* and *b* axes are equal, and all three axes are at right angles. The symbol (111) indicates a bipyramid which is acute when the *c* axis is longer than the lateral axes (Fig. 56), or obtuse when the *c* axis is shorter than the others (Fig. 57).

Since the lateral axes are equal and interchangeable, a form whose symbol is (101) will be a secondary bipyramid, instead of one consisting of dome planes, as in the orthorhombic system (Fig. 58).

Symbols such as (211) or (331), etc., indicate the ditetragonal bipyramid (Figs. 59 and 60), since the two or three can be applied to each lateral axis in turn, thus indicating two planes in each octant.

Similarly there are three prisms: a primary, (110) (Fig. 61); a secondary turned 45° to it, (100) (Fig. 62); and a ditetragonal prism, (210) (Fig. 63). These with the basal plane represent the simple holohedral forms of the system. Figure 64 shows a combination of several of these planes.

Hemihedral forms are constructed on the same plan as were those in the systems heretofore described. For example, when the alternate pyramid faces only are developed, a bisphenoid results (Fig. 65). It may be either positive or negative. If the planes in alternate octants of a ditetragonal pyramid are developed, the tetragonal scalenohedron is produced. Tetragonal scalenohedrons possess two planes

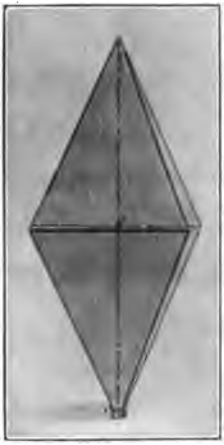


FIG. 58.—Model of a secondary bipyramid.

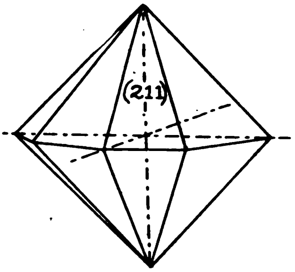


FIG. 59.—Ditetragonal bipyramid

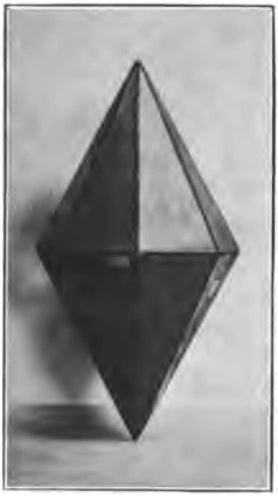


FIG. 60.—Model of a ditetragonal bipyramid.

of symmetry intersecting at right angles in the *c* axis, which is an axis of alternating symmetry. They are so well represented in chalcopyrite that the class has been called the "chalcopyrite class of symmetry."

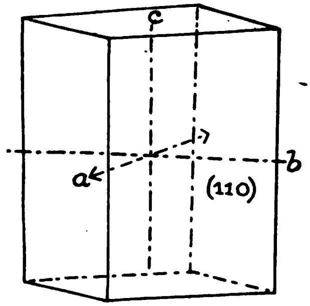


FIG. 61.—Primary prism

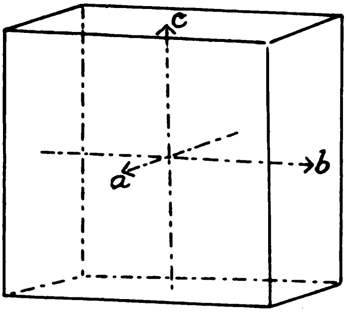


FIG. 62.—Secondary prism

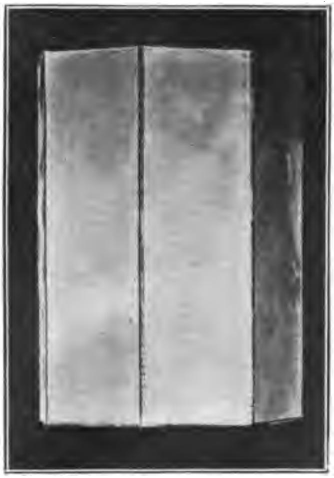


FIG. 63.—Model of a ditetragonal prism.

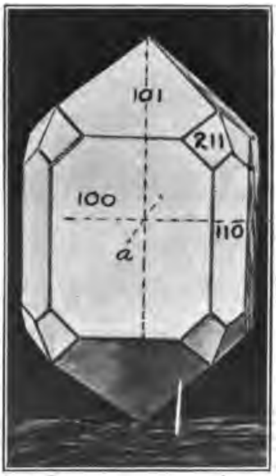


FIG. 64.—Combination of primary prism (110), secondary prism (100), secondary bipyramid (101), and ditetragonal bipyramid (211).

Figure 66 represents the most usual chalcopyrite crystal. It is composed of the positive scalenohedron. Pyramid planes with the symbol (201) often appear on the edges. The scalenohedrons may be either acute or obtuse.

Figure 67 represents a form composed of the prism (110), scalenohedrons (111) and (101), and the basal plane (001).

Two kinds of twins are common. In one the twinning plane is (111) and produces a form so similar to the twin characteristic of the mineral spinel as to be called the "spinel twin." (The "spinel twin" proper is a form in the regular system.)

The faces of one of the scalenohedrons are bright, while those of the other are dull.

In the second form of twinning, a central crystal (201) is surrounded by four other crystals which are joined on the primary pyramid plane (111), forming a composite twin (Fig. 68). As is generally the case with all minerals, massive forms are the rule and evident crystals the exception.


FIG. 65.—Model of a bisphenoid

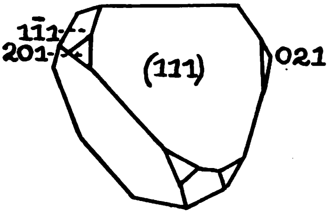


FIG. 66.—Chalcopyrite

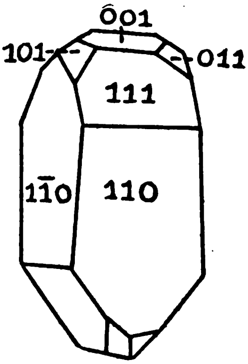


FIG. 67.—Chalcopyrite, French Creek, Pennsylvania.

The color of chalcopyrite is bronze yellow and its streak is greenish black. Because of surface alterations it readily tarnishes, and takes

PLATE VII

a, Group of pyrite cubes, showing striations, Central City, Colorado.

b, Pyrite. A pyritohedron and cubes, Colorado on beautiful iridescent colors. The vivid blue is due to the formation of covellite (CuS).

The Cordilleran region from Arizona to Montana furnishes large quantities of chalcopyrite. Many fine crystals have been found at French Creek, Pennsylvania, the Hartz Mountains, and Cornwall.

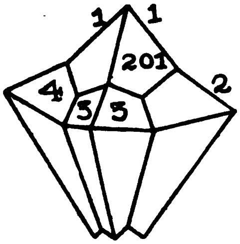


FIG. 68.—Chalcopyrite, Neudorf. Twinned parallel to (111).

SUMMARY

Chalcopyrite.—$CuFeS_2$; Cu = 34.5 per cent, Fe = 30.5 per cent, S = 35 per cent. Tetragonal; symmetry ditetragonal alternating (chalcopyrite class); $a:c = 1:0.985$. Common forms (111), (101), (211), (001), (201), (114,) (441); twinned about normal of (111). Brittle; fracture conchoidal.

Hardness = 4; gravity = 4.2. Brass yellow, tarnishes blue; streak greenish black; metallic; opaque.

Fusible; soluble in nitric acid.

Western United States, Pennsylvania, Harz, Cornwall.

Pyrite

This iron sulphide is more abundant than any mineral thus far considered. It is found in all kinds of rocks, with all kinds of mineral associates, and in all parts of the world. In Illinois it occurs in the underlying rocks—the shale, limestone, and sandstone, and in the sand and gravel carried in by Pleistocene glaciers.

The name pyrite (πῦρ, Greek "fire") was used by Dioscorides and Pliny in the first century after Christ for minerals which gave sparks when struck by the hammer, and was applied not only to minerals in which the sparks are due to the combustion of the mineral itself but to hard minerals like flint in which the sparks are due to glowing particles intensely heated by the friction.

Pyrite differs from the iron sulphide already considered, pyrrhotite, in being neither magnetic nor bronze colored, and from the copper iron sulphide, chalcopyrite, in being brass yellow and not deep yellow as in chalcopyrite.

It occurs as masses, large and small crystals, and minute yellow specks in sedimentary, igneous, and metamorphic rocks.

Two forms of crystals are common and several others abundant. One of the most typical is that which has the outline of a cube (100) (Plate VII *a*), but whose true symmetry is indicated by the striations on each face. These striations show that the cube is built up by repetition of many planes of a form which is so characteristic of pyrite as to have been named the "pyritohedron" (pentagonal dodecahedron) (Plate VII *b*). The pyritohedron is formed when the alternate quarters of the four-faced cube (the inner part of Fig. 69) are developed, beginning with the plane (210). The black strips with which the glass faces of the outer figure are bound mark the pyritohedron. Clear-cut pyritohedrons are so common that every collector can obtain them. Occasionally a form shown in Figure 70, called a diploid, is found. It results when the plane (321) and each alternate plane in the right-hand octant of the hexoctahedron and the planes of the like symbol in the other octants are developed to the exclusion of their neighbors.

FIG. 69.—Pyritohedron derived by disappearance of tetrahexahedral planes darkened, and growth of the other planes.

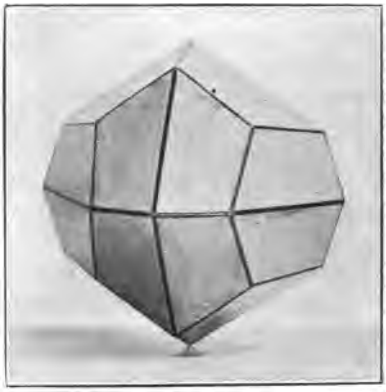


FIG. 70.—Model of a diploid

Both the diploid and the pyritohedron agree in this, that if revolved around any one of the four octahedral axes, i.e., the lines extending through the center of the crystal and perpendicular to an octahedral plane (Fig. 23), each of its faces would be in the position previously occupied by the adjoining face three times during a complete revolution. The faces are said therefore to have four trigonal axes. If revolved around the crystallographic axes (*a*, *b*, *c*) the planes are in similar positions twice during a complete revolution and hence these axes are called digonal axes. Since planes through any two of these digonal axes (*a* and *c*, or *b* and *c*, or *a* and *b*) are planes of symmetry, the digonal axes are called didigonal axes. Pyrite crystals have three didigonal axes. Their faces are in pairs about a center. Hence the pyrite class of the regular system has a center, three planes, three didigonal and four trigonal axes of symmetry. This symmetry is called tesseral central symmetry.

Cube, octahedron, pyritohedron, and diploid appear in various combinations. The edges of the pyritohedron (210) are truncated by the cube (100) (Fig. 71).

FIG. 71.—Model of a combination of pyritohedron (210) and cube (100).

Etching with aqua regia produces figures symmetrically arranged in respect to the cube planes.

Sulphides of nickel and cobalt are often found in pyrite as isomorphous intermixtures, i.e., mixtures of substances having the same crystalline form. Chalcopyrite, marcasite, and silver sulphide are often associated with it.

The most important impurity, however, is gold, which is often present as a metal scattered through the pyrite in invisible particles. Much of the gold of the world is now obtained by crushing, roasting, smelting, and cyaniding pyrites, and much of the placer gold may have originally come from the same source.

The chief use of pyrite is in the manufacture of sulphuric acid, sulphur, and iron oxide to be employed as polishing powder and paint. Iron for steel manufacture cannot be obtained from it, since thorough separation of the sulphur is almost impossible and a fraction of 1 per cent remaining in the iron renders it brittle while hot.

SUMMARY

Pyrite.—FeS_2; Fe=46.6 per cent, S=53.4 per cent. Regular; pyrite class: (100), (111), (210), (321), (421). Supplementary twins; granular; massive; brittle; fracture conchoidal.

Hardness=6; gravity=5.1. Pale brass yellow; streak greenish black; metallic; opaque.

Burns on charcoal and gives off SO_2; fuses to magnetic globules; soluble in nitric acid.

Ubiquitous.

Marcasite

The same chemical composition is ascribed to marcasite as to pyrite, namely, FeS_2. But there are pronounced physical differences. Marcasite crystallizes in the orthorhombic system and in the holosymmetric class. The crystals have a center of symmetry; three planes of symmetry intersecting at right angles in the crystallographic axes; and the *c* axis is a didigonal axis of symmetry, that is, if revolved around the *c* axis the planes assume similar positions twice in one complete revolution, making the *c* axis a digonal axis. Since planes of symmetry intersect in this axis, it is called a didigonal axis. A form common to marcasite is composed of the prism (110), base (001), and brachydomes (011) and (013) (Fig. 72). Prisms of marcasite are usually terminated by various brachydome planes (Fig. 73). Isolated crystals are rare. Because of multiple twinning they generally show jagged outlines and re-entrant angles. Before marcasite was distinguished from pyrite, these forms were called "spearhead pyrites," "cockscomb pyrites," "radiated pyrites," "hepatic pyrites,"

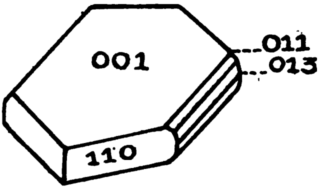


FIG. 72.—Marcasite

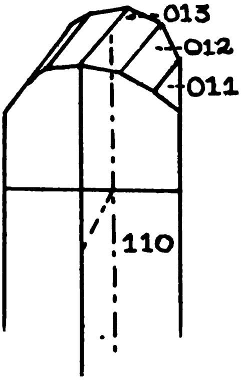
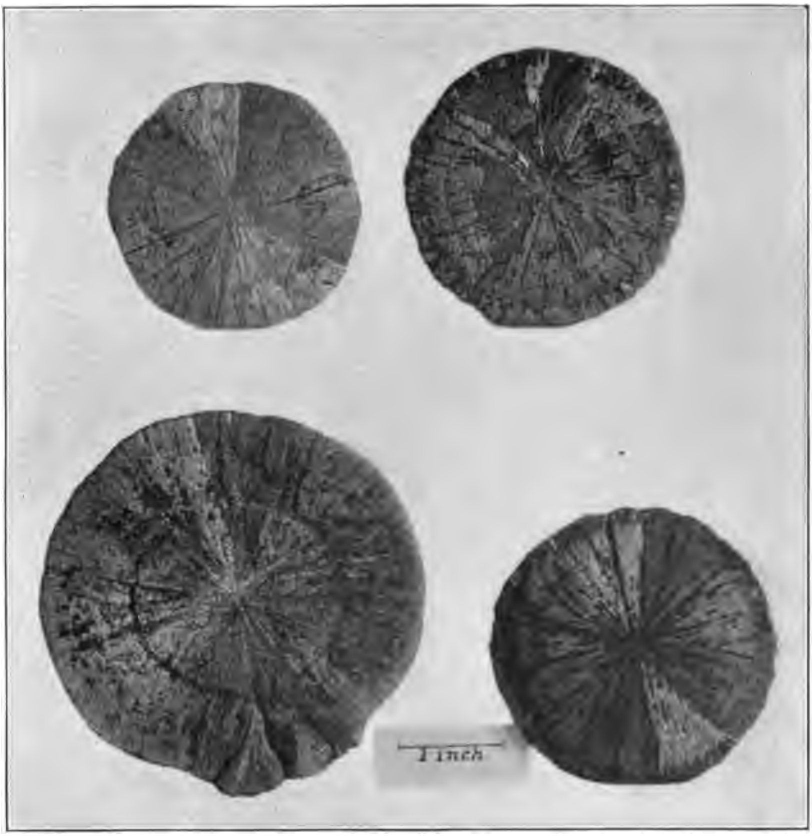


FIG. 73.—Marcasite

PLATE VIII

Marcasite, Jo Daviess County, Illinois

PLATE IX



Marcasite disks, Gulf Mine, Sparta, Randolph County, Illinois

etc. Four or five individuals consisting of various dome and basal planes twinned parallel to the prism produce the "spear-head pyrites" (Fig. 74). "Cockscomb pyrites" result from repeated twinning parallel (110) so as to produce individuals parallel to each other (Fig. 75). The prisms are short and the striated basal plane long. Radiated, nodular, and stalactitic forms are abundant (Plate VIII). More marcasite than pyrite is found in Illinois. No. 3287 from Sparta shows disks which are not surpassed in abundance and perfection by any locality (Plate IX).

Plate X shows a portion of a large radiated mass and Plate XI a coating of marcasite on cubes of galena which are resting upon a botryoidal mass of sphalerite, well illustrating the association of the sulphides.

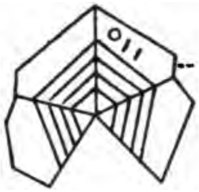


FIG. 74.—"Spearhead pyrites"

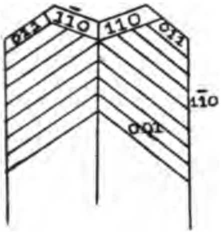


FIG. 75.—"Cockscomb pyrites"

Haidinger (1845), recognizing the orthorhombic form of marcasite, reserved Pliny's term pyrite for the regular form and applied the old Moorish word "marcasite" to the orthorhombic. It is a common error to use the name pyrite when marcasite is meant. Marcasite is orthorhombic, white in color and streak, not as heavy and more easily decomposed than pyrite. Even in museum cases it disintegrates and becomes covered with white efflorescent iron sulphate (melanterite) and forms sulphuric acid which attacks the material upon which it rests. Its instability may be due to minute spicules of troilite (FeS), a mineral heretofore identified in meteorites only.

When marcasite is heated to 200° C. in a sealed tube with a copper sulphate solution, it yields a solution entirely ferrous. Pyrite treated in the same way yields a solution 19.9 per cent ferrous and 80.1 per cent ferric. Hence the formula of marcasite is $\overset{\text{II}}{\text{Fe}}\text{S}_2$ while that of pyrite is $4\overset{\text{III}}{\text{Fe}}\text{S}_2$ and $\overset{\text{II}}{\text{Fe}}\text{S}_2$.

Since marcasite is most common in limestones and shales, and pyrite in crystalline rocks, their physical differences are doubtless due to their origin—marcasite having been hastily deposited from cold solutions, and pyrites slowly deposited from hot solutions, pyrite representing the more successful molecular grouping and showing that metamorphism produces in the lower zones of the earth's crust minerals of more complete symmetry, higher specific gravity, and greater hardness than those found in the upper zones.

Marcasite has been made in the laboratory from an acid solution and with temperatures not above 300° C. When the solution was neutral, pyrite crystals were formed. The most favorable conditions were found to be an acidity amounting to about 1.2 per cent free sulphuric acid and a temperature of 100°. At 450° marcasite changes to pyrite.

Both marcasite and pyrite are common fossilizing material because of the reducing action which decaying organisms exert upon iron sulphate solutions. Marcasite decomposing in moist air forms sulphuric acid, which can change the limestones surrounding it to gypsum.

SUMMARY

Marcasite.—FeS_2; Fe=46.6 per cent, S=53.4 per cent. Orthorhombic; holosymmetric; $a:b:c=0.766:1:1.234$; forms (110), (001), (011), (018); twinned on (110). Crystals grouped, nodular, stalactitic, radiated, massive. Cleavage imperfect (111); brittle; fracture uneven.

Hardness=6; gravity=4.8. Pale brass yellow; streak greenish gray; metallic; opaque.

Soluble in nitric acid. Fuses readily.

Ubiquitous.

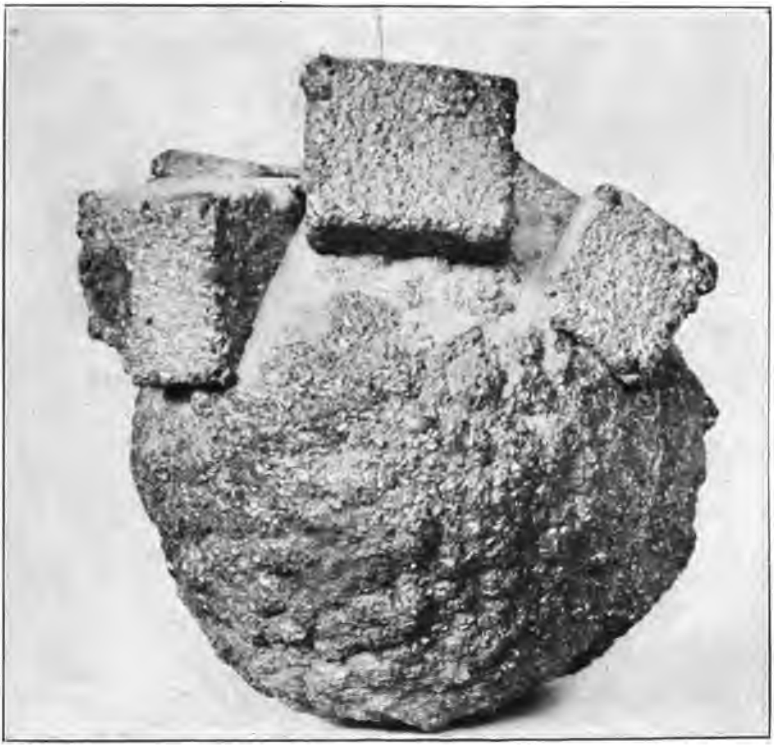
Arsenopyrite

Arsenopyrite resembles marcasite in its crystallography (Figs. 76 and 77) but is whiter, has a black streak, and is softer and heavier. It often contains as high as 9 per cent of cobalt in the form of an isomorphous intermixture of the cobalt sulphide, glaucodot. Arseno-

PLATE X

Marcasite, showing radiated internal structure

PLATE XI



Marcasite coating galena, Marsden Mine, Jo Daviess County, Illinois

pyrite is the chief source of arsenic, a metal used principally in the manufacture of Paris green, in various medicinal compounds and embalming fluids, and in glass and enamel manufacture.

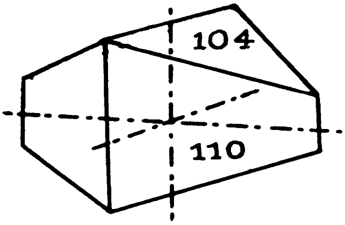


FIG. 76.—Arsenopyrite

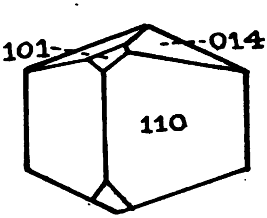


FIG. 77.—Arsenopyrite

SUMMARY

Arsenopyrite.—FeAsS; Fe=34.3 per cent, As=46.0 per cent, S=19.7 per cent. Orthorhombic; holosymmetric; $a:b:c=0.677:1:1.08$; (110), (011), (014); twinned on (101); massive; cleavage fair (110); brittle; fracture uneven.

Hardness=5.5; gravity=6. Silver white; streak grayish black.

Soluble in nitric acid.

Freiberg, Cornwall, Ontario, Washington.

CLASS III. SULPHANTIMONITES, SULPHARSENITES

PYRARGYRITE GROUP

Pyrargyrite, a silver sulphantimonite, and proustite, a silver sulpharsenite, called the "ruby silver ores" because of their wine-red color when fresh, are excellent examples of isomorphism, since they crystallize in forms very similar and with angles nearly identical, though one contains antimony and the other arsenic. Their structure places them in the hexagonal system, and their symmetry is said to be "ditrigonal polar" (tourmaline class). It is polar, inasmuch as the crystals are different at different ends. If the difference is not shown by developed planes, it may nevertheless be disclosed by the striations on the prism planes, since the striations are not symmetrical toward both ends. The symmetry is ditrigonal, since three planes of symmetry intersect in the *c* axis, and if the forms are revolved around this axis the planes are in a similar position three times in one complete revolution (Fig. 78).

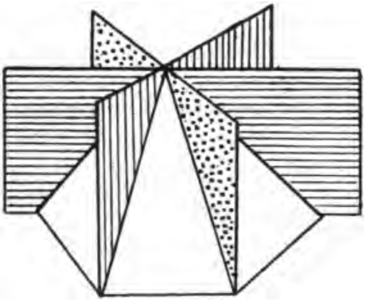


FIG. 78.—Symmetry planes of a ditrigonal polar crystal.

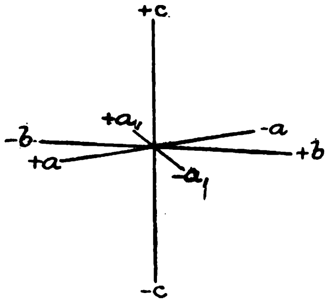


FIG. 79.—Axes of hexagonal system

In the hexagonal system are grouped those crystals which have three lateral axes of equal length intersecting each other at 60°, and perpendicular to them a vertical axis longer or shorter than they are. The method of naming the axes can be understood from Figure 79. The holosymmetric (holohedral) forms are three pyramids and three prisms, and the ratios are always given thus: $a:b:\bar{a}_1:c$. The sum of the intercepts on the first three is always zero. If (*hkil*) represents any symbol, then $h+k+i=0$. The primary pyramid (Fig. 80) is a form whose parameter is $1:\infty:\bar{1}:1$ and whose symbol is $(10\bar{1}1)$.

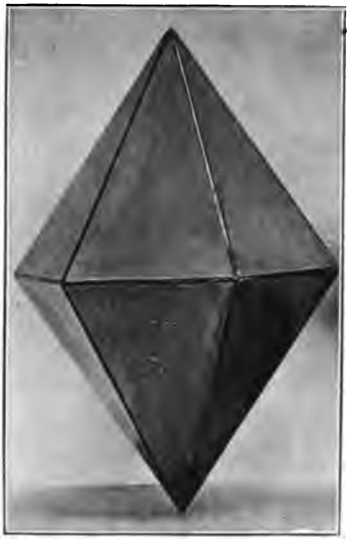


FIG. 80.—Model of a primary pyramid

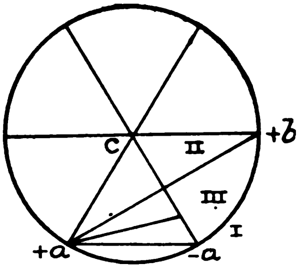


FIG. 81.—Basal section showing relation of primary, secondary, and dihexagonal pyramids and prisms. $\text{I}=(10\bar{1}1)$, $\text{II}=(11\bar{2}1)$, $\text{III}=(21\bar{3}1)$.

Parameter	Ratio	Symbol
$1:\infty:\bar{1}:1$	$\frac{a}{1}:\frac{b}{0}:\frac{\bar{a}_1}{1}:\frac{c}{1}$	$(10\bar{1}1)$

The diagonal (or "secondary") pyramid, whose relation to the primary pyramid is shown in Figure 81, is one whose parameter is $2:2:\bar{1}_1:2$.

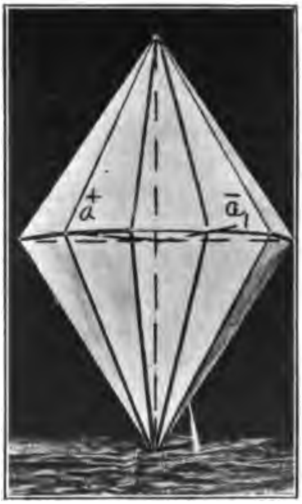


FIG. 82.—Model of a dihexagonal bipyramid.

Parameter	Ratio	Symbol
$2:2:\bar{1}_1:2$	$\frac{1}{1}:\frac{1}{1}:\frac{\bar{1}}{2}:\frac{1}{1}$	$(11\bar{2}1)$

The dihexagonal pyramid (Fig. 82) is a form whose parameter may be $\frac{3}{2}:3:\bar{1}:3$.

Parameter	Ratio	Symbol
$\frac{3}{2}:3:\bar{1}:3$	$\frac{a}{2}:\frac{b}{1}:\frac{\bar{a}_1}{3}:\frac{c}{1}$	$(21\bar{3}1)$

FIG. 83.—Model of a primary hexagonal prism.

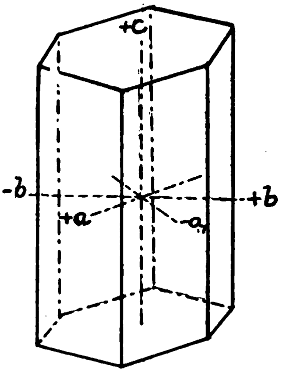


FIG. 84.—Secondary hexagonal prism

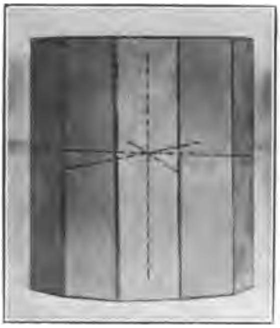


FIG. 85.—Model of a dihexagonal prism.

The relation of all three of these pyramids to each other is shown by a ground plan of the lateral axes (Fig. 81). The *c* axis is simply a point.

The three prisms are similar and their symbols are identical with those of the three pyramids, save that the number applied to the *c* axis is always zero (see Figs. 83, 84, 85).

Two hemihedral forms are common; first, that which results when the unit pyramid planes in alternate sextants only are developed. If the start is made with the front sextant $(11\bar{0}1)$, a positive rhombohedron (*R*) results (Fig. 86). If the start is made with $(01\bar{1}1)$, a negative rhombohedron ($-R$) is produced. If the two planes in each alternate sextant of a dihexagonal pyramid are developed, a scalenohedron is formed

FIG. 86.—Rhombohedron (R) resulting from disappearance of darkened planes of the interior figure—a hexagonal bipyramid.

FIG. 87.—Model of a positive scalenohedron.

FIG. 88.—Model of a scalenohedron truncated by a rhombohedron (R).

FIG. 89.—Model of a prism truncated by negative $\frac{1}{2}R$.

($21\bar{3}1$) (Fig. 87). A positive rhombohedron and scalenohedron are united in Figure 88, while in Figure 89 a prism is truncated by the negative $\frac{1}{2}$ rhombohedron, $-\frac{1}{2}R$.

Crystals of pyrargyrite and proustite occur in forms which are combinations of the secondary prism $(11\bar{2}0)$ terminated above with the plus rhombohedron $(10\bar{1}1)$, the flat minus rhombohedron $(01\bar{1}2)$, and the flat scalenohedron $(21\bar{3}4)$, while below appear the scalenohedrons $(21\overline{31})$ and the rhombohedrons $(01\overline{12})$ and $(01\overline{14})$ (Fig. 90). As usual with most minerals, well-developed crystals are rare. Ordinarily pyrargyrite and proustite occur in masses.

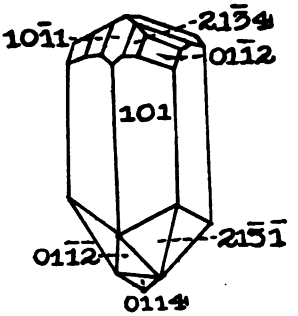


FIG. 90.—Pyrargyrite, crystal form.

Pyrargyrite varies in color from the darkest varieties, which are of a deep ruby shade in thin splinters, to the lightest varieties, which are clear wine color. Upon exposure to light, pyrargyrite becomes dead black. It should therefore be sheltered from light if the reddish color is to be preserved. The streak of pyrargyrite is purplish red, while that of proustite is scarlet.

Like minerals in all systems other than the regular, these minerals divide entering light into two rays vibrating at right angles to each other and hence differently refracted. One of the rays is called the ordinary (ω) and the other the extraordinary (ϵ).

SUMMARY

Pyrargyrite.—Ag_3SbS_3; Ag = 59.8 per cent, Sb = 22.5 per cent, S = 17.7 per cent. Hexagonal; ditrigonal polar (tourmaline class); $a:c = 1:0.789$; $(11\bar{2}0)$, $(11\bar{0}1)$, $(01\bar{1}2)$, $(21\bar{3}1)$, $(21\bar{3}4)$, $(01\bar{1}4)$; massive. Cleavage imperfect $(11\bar{0}1)$ and $(10\bar{1}0)$; brittle; fracture conchoidal.

Hardness = 2.5; gravity = 5.8. Black to ruby, streak purplish red; metallic; adamantine; translucent. Refraction strong; mean refractive index in sodium light is 2.98 (stronger than that of diamond, and surpassed by cinnabar alone, 3.02).

Easily fusible; soluble in nitric acid.

Guanajuato, Mexico; Chili; Cordilleran states.

Proustite.—Ag_3AsS_3; Ag = 69.4 per cent, As = 15.2 per cent, S = 19.4 per cent. Crystallography similar to pyrargyrite; $a:c = 1:0.304$.

Physical properties similar to pyrargyrite, but color lighter and streak scarlet. $\omega = 2.94$.

Localities similar to pyrargyrite.

TETRAHEDRITE GROUP

In this group are two well-crystallized copper minerals, tetrahedrite (Cu_3SbS_3) and tennantite (Cu_3AsS_3), which are related to each other as were the two silver minerals, pyrargyrite and proustite. So definite are they in crystal habit that they have been chosen to furnish the name of a crystal class, the tetrahedrite class (already illustrated by the diamond).

The tetrahedron (111) is always developed, sometimes alone (Fig. 91), but usually combined with other tetrahedrons, trapezohedrons, and dodecahedrons. A common combination is a positive tetrahedron (111) with edges beveled by positive and negative three-faced tetrahedrons (211), and with corners truncated by the minus tetrahedron ($1\bar{1}1$) and beveled by the dodecahedron (110) (Fig. 92). The negative tetrahedron appears as a small triangle on each corner and is usually dull or pitted with triangular markings, while the positive faces are bright.

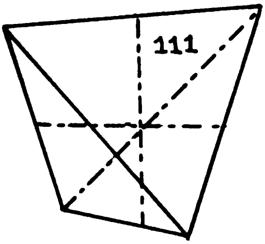


FIG. 91.—Prevailing form of tetrahedrite.

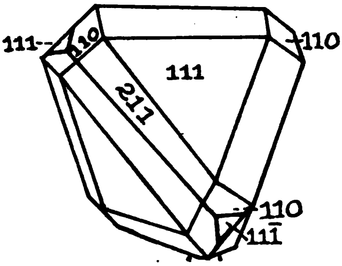


FIG. 92.—Characteristic form of tetrahedrite.

When complementary forms of a three-faced tetrahedron (211) are present, the positive form is often striated perpendicularly, while the negative is striated parallel to the dodecahedron edge which it truncates.

The edges and corners of one tetrahedrite crystal often project from the faces of another—a kind of twinning derived by a half-turn of the projecting crystal about a line normal to (111).

In tennantite, dodecahedral or cubic faces usually predominate (Fig. 93).

The old German miners called both of these minerals (tetrahedrite and tennantite) *Fahlerz* ("pale ore"), and that term included several varieties which were later divided and named according to the locality in which they are found or according to some peculiarity due to varying composition. They contain not only copper, antimony, arsenic, and sulphur, but often bismuth, lead, silver, mercury, zinc, and iron in varying amounts, vicariously replacing each other.

Some of the varieties are the following: (1) freibergite (Freiberg, Saxony) often contains as much as 30 per cent of silver and is lighter than ordinary tetrahedrite in color; (2) schwatzite (Schwatz, Tyrol) contains 16 per cent mercury and occurs in black, drusy, dodecahedrons; (3) binnite (Binnenthal, Switzerland) appears in brilliant cubic crystals; (4) sandbergerite contains zinc and shows a tendency to develop large faces of the three-faced tetrahedron (211) (Fig. 94).

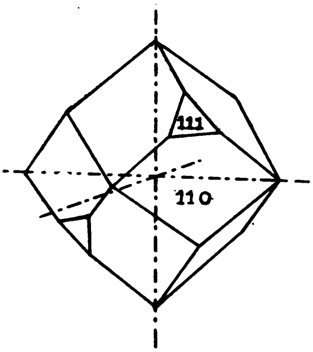


FIG. 93.—Tennantite (schwatzite)

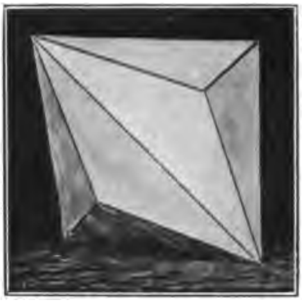


FIG. 94.—Model of sandbergerite

Tetrahedrite crystals are often coated with brassy, drusy chalcopyrite (Cornwall). They can all be recognized by polar symmetry, metallic luster, absence of cleavage, and reactions for copper, together with either arsenic or antimony.

Massive tetrahedrite is worked in Germany, Cornwall, and in many places in the Cordilleran states as a source of copper and silver.

SUMMARY

Tetrahedrite.—Cu_3SbS_3; Cu=46.8 per cent, Sb=29.6 per cent, S=23.6 per cent. Regular; symmetry ditrigonal polar; (111), $(11\bar{1})$, (110), (211); twinning axis the normal to (111); brittle; fracture subconchoidal.

Hardness=3.5; gravity=4.7. Lead gray; streak dark brown; metallic; opaque.

Fusible; soluble in nitric acid.

Germany, Bohemia, Cornwall, western United States.

CLASS IV. HALOIDS

THE SALT GROUP

The two most important minerals of this group are halite, sodium chloride (common salt), and sylvite, potassium chloride. Being soluble in water, they may be distinguished by their taste. While both are saline, sylvite is bitter.

Sylvite—the *sal digestivus sylvii* of the old pharmacists—has long been used for medicinal and chemical purposes. It was first discovered in the volcanic sublimations of Vesuvius, but larger quantities and finer specimens are now obtained at Stassfurt, Germany.

Halite has the distinction of being the mineral most largely used as a food. Other minerals furnish food for plants and thus indirectly sustain the life of man, but halite is the only mineral which is eaten in its natural state. It is also one of the most useful of minerals in chemical and manufacturing industries—glass manufacture, chlorine and soda works, etc.

Halite is the most abundant salt in ocean water, and in many seas in arid regions in various parts of the world. Salt Lake, Utah, contains 20.19 per cent sodium chloride; the Dead Sea, Palestine, only 7.8 per cent. The Dead Sea contains more magnesium chloride, about 11 per cent, and about 2 per cent of potassium chloride. Its total content of salts exceeds that of Salt Lake, being about 25 per cent.

By the evaporation of such seas in preceding geological periods, great beds of salt have been laid down. Such are those of New York, Michigan, Louisiana, Kansas, Nevada, and other states. The New York bed most utilized is seventy-five feet thick and lies at a depth of from one thousand to two thousand feet below the surface. The salt is obtained there, as it is in Michigan, Louisiana, Kansas, and other places, by driving pipes down to the bed, forcing hot water down to dissolve the salt, and carrying the brine thus produced up to evaporating basins, where it is collected, purified, and made ready for market. In some places salt is mined just as is coal. The great chambers remaining after the removal of mountainous masses of salt in some of the mines of Germany, Austria, and Russia are among the most interesting and beautiful underground caverns that are to be found.

Salt obtained by evaporation of brines often exhibits skeletal cubes with cavernous faces (Fig. 95). Natural crystals show quite perfect cubes. Ordinarily both halite and sylvite occur in granular and massive condition and contain magnesium chloride, magnesium sulphate, and calcium sulphate as impurities.

When pure, salt is transparent and colorless. But varying tints of yellow, red, and blue are common. The coloring material is usually some iron oxide. It has been suggested that the deep blue color in salt (see No. 3288 from Stassfurt) may be due to metallic potassium.

Both halite and sylvite are highly diathermanous, allowing free passage of heat as other transparent bodies allow passage of light, and cleavage blocks are used to inclose gases in a tube with transparent ends which will readily transmit heat rays.

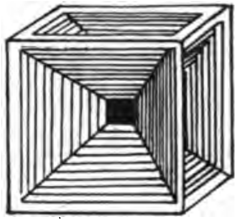


FIG. 95.—Halite cube from salt brine.

SUMMARY

Halite.—NaCl; Na = 39.4 per cent, Cl = 60.6 per cent. Regular; (100); massive. Cleavage perfect (100); brittle; conchoidal.

Hardness = 2.5; gravity = 2.2. Colorless; streak white; vitreous; transparent; refraction weak, $n = 1.54$.

Soluble in three volumes of water; taste saline; fusible.

Lakes in arid regions, New York, Michigan, Louisiana, Kansas, Germany, Poland, Russia.

Sylvite.—KCl; K = 52.4 per cent, Cl = 47.6 per cent. Regular; symmetry holoaxial; (100); massive. Cleavage perfect (100); brittle; fracture uneven.

Hardness = 2; gravity = 1.9. Colorless; streak white; vitreous; transparent; refraction, $n = 1.49$.

Soluble in three volumes of water; taste saline, bitter; fusible.

Volcanic regions; Stassfurt.

Fluorite

Fluorite (CaF_2) occurs commonly in beautiful, clear-cut cubic crystals. Few minerals show their crystal form so plainly. The edges of the cubes are often beveled by the four-sided cube (310) (Fig. 96) or by a hexoctahedron (421) (Fig. 97). The flat four-faced cube is so characteristic that it has been called the "fluoroid."

The most typical twinning of fluorite is that where two cubes interpenetrate about a line normal to (111) with the result that the corners of one cube project from the faces of the other (Fig. 98). At a point where these corners emerge, the cube face is raised into low "vicinal" faces which form a flat four-faced cube with very high parameters, for example, 32:1:0. "Vicinal" faces often replace simple faces with low parameters. Multitudes of minute cubic crystals often cover the faces of the large cubes without detracting from their luster, since the minute faces are parallel to the large ones. Fluorite also occurs in granular and compact masses.

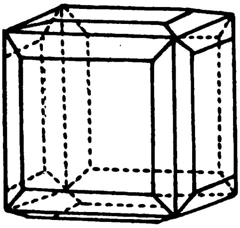


FIG. 96.—Fluorite

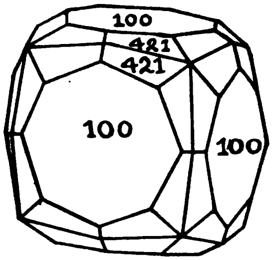


FIG. 97.—Fluorite

Its cleavage is remarkably perfect, yielding octahedrons (Plate XIII). This trait, together with its vitreous luster, aids in the ready identification of the mineral. The cubic faces have a higher luster than have the cleavage faces. Natural octahedrons are usually dull. Fluorite displays many beautiful colors. Large yellow cubes with corners beveled by (421) are found at Mehenoit, Cornwall; and transparent yellow cubes (see No. 503), at Durham. Beautiful purple crystals, No. 502 from Alston and No. 3852 from Cumberland, are shown. Pink and rose-red octahedrons are found near Chamonix, and at the island of Siglio (near Elba). Beautiful green, plum-

PLATE XII

Fluorite group from Rosiclare, Hardin County, Illinois

a, Fluorite cubes, Rosiclare, Illinois

b, Octahedrons cleaved out by ten-year-old boy, showing ease and regularity of cleavage.

colored, and amethystine crystals from the north of England adorn many museums. Since the colors are in layers parallel to cubic faces, some lilac cubes have a yellow center (Derbyshire) and some a deep green center. Amethystine (Nos. 3296 and 3297), green (Nos. 2278 and 2567), and colorless (No. 1788) specimens, all from Rosiclare, Hardin County, give an idea of the color of Illinois occurrences. Large crystal groups are shown in Nos. 708 and 958. No. 908 is a typical massive specimen. The most complete exhibit of Illinois fluorite is shown in the cases devoted to the economic exhibits.


FIG. 98.—Model of fluorite twin

When specimens of fluorite are heated, they lose in weight and color, and hence are thought to owe their color to hydrocarbon compounds. No relation has been traced between composition and color. Green and red crystals are strongly phosphorescent, that is, if heated above 212° F. or held in sunlight, when taken into a dark room they are luminous. The phenomenon called "fluorescence" is named from this mineral, since it is best illustrated when some richly colored specimens are held in the sunlight. They become hazy at a slight depth below the surface and diffuse from this superficial layer a plum-blue color. When viewed by transmitted light, they are light green. This fluorescence is due to transformation of light rays within the mineral, so that those emitted are of greater wave-length than those which entered.

Fluorite is low in refraction ($\omega = 1.43$). Were colorless isotropic crystals more abundant, the mineral would find extensive use in the manufacture of lenses and microscopic objectives where achromatic light is desired. It is used in the production of ultra-violet rays, for making vases and ornaments (Derbyshire, England), and for enamel and glass manufacture; but the largest quantities are employed as a flux in iron smelting and in similar operations where a fluid slag is sought.

Being the only common mineral which contains fluorine in any large proportion, fluorite is the chief source of hydrofluoric acid. Moissan used it for vessels and stoppers in experiments on the isolation of fluorine, since it is one of the few substances which is not attacked by the gas.

Fluorite occurs chiefly associated with metallic ores, calcite, barite, and in tin-bearing veins which are marked by the presence of other minerals containing fluorine, such as topaz, lepidolite, tourmaline, and apatite. Illinois leads all other states in the production of fluorite, some years more than a million dollars' worth having been sold, greatly to the advantage of the steel industry, the manufacture of enameled bath tubs, the production of hydrofluoric acid, etc.

SUMMARY

Fluorite.—CaF_2; Ca=51.1 per cent, F=48.9 per cent. Regular; holosymmetric; (100), (310), (421). Massive; interpenetrant twins on axis normal to (111). Cleavage, perfect (111); brittle; fracture subconchoidal.

Hardness=4; gravity=3.2. Purple, blue, green, yellow, brown; streak white; vitreous; transparent. Refraction weak ($\omega=1.44$); dispersion weak.

Fusible; soluble in nitric acid.

England, Germany, France, Illinois, Kentucky, Colorado.

Cryolite

Cryolite is a colorless or pure white translucent mineral composed of sodium and aluminium fluoride (Na_3AlF_6). It is well named "icestone" (*χρυος*, "frost" and *λιθος*, "stone") because of the translucence of its white masses, because of its low melting-point (a splinter fuses in a candle flame), and because it has been obtained in the greatest amounts in the land of ice, West Greenland, where it was discovered near the town of Ivigtut in 1795. It was long the only source of aluminium and is still an important ore, though today bauxite, a brownish, earthy, hydrated aluminium oxide ($Al_2O_3+2H_2O$) found in quantities in the southern states, furnishes most of the aluminium of commerce. Free crystals of cryolite are so rare that the author has never noticed one. Optical examination of crystalline masses and etching with sulphuric acid, however, show the crystals to be repeatedly twinned and to belong to the "triclinic system." In masses they resemble cubes placed in parallel position. Their cleavage also appears to be parallel to cubic planes, hence it is easy to mistake their crystallography.

The cleavage, oblique striations, and hardness (2.5) distinguish cryolite from colorless fluorite and similar minerals. Heated with sulphuric acid, cryolite gives off hydrofluoric acid (HF).

SUMMARY

Cryolite.—Na_3AlF_6; Na=32.8 per cent, Al=12.8 per cent, F=54.4 per cent. Triclinic; (110), (001), (101); massive; cleavage, perfect, parallel (001), nearly perfect parallel (110), (101); brittle; fracture uneven.

Hardness=2.5; gravity=3. Colorless; vitreous; transparent; refraction weak, $\beta=1.36$; birefringence weak, positive.

Easily fusible; soluble in sulphuric acid.

Greenland.

CLASS V. OXIDES

Of the minerals which consist of one or more basic elements united with oxygen, about seventeen are abundant and important. The oxides of silicon, that is, quartz, chalcedony, and opal, will be considered first; and second, the oxides of the metals, such as cuprite, zincite, corundum, hematite, spinel, magnetite, franklinite, chromite, cassiterite, rutile, pyrolusite, manganite, goethite, and limonite, will be taken up next.

Quartz

Quartz (SiO_2) is the most abundant mineral in the world. It is the chief constituent in the sands of the deserts and of the ocean shores, in the great layers of sandstone and quartzite which underlie the plains and outcrop in the mountains, and in most of the rocks that form the cores of mountain ranges.

No mineral has received more study than quartz. It furnished that thoughtful Danish physician, theologian, and geologist, Steno (1669), material with which to establish the "law of the constancy of a crystal angle," and it has been the subject of study for mineralogists ever since, seeming still to be able to reward the investigator with new facts.

The Greeks thought quartz to be ice so thoroughly frozen as to have lost the power of melting, and hence named it *κρύσταλλος*, that is, "ice," and today many persons say crystal when they mean quartz. The name "quartz" is an old German mining term used since the sixteenth century and now common to many languages.

Crystals of quartz are more abundant than those of any other mineral. They occur in the hexagonal system, and their symmetry is trigonal holoaxial, i.e., they have no plane nor center of symmetry but if revolved around the *c* axis their planes occupy similar positions three times during a complete revolution.

Prism $(10\bar{1}0)$ and rhombohedron $(10\bar{1}1)$ planes are nearly always present and combined, as shown in Figure 99. In Hungary and Brazil are found crystals which contain these planes only. It will be seen that when revolved around the *c* axis an upper rhombohedron

PLATE XIV

a, Smoky quartz, "cairngorm," from Montana.

b, Quartz, Montgomery County, Arkansas

PLATE XV

Quartz group, Montgomery County, Arkansas

would be in the front three times during a complete revolution; hence the crystals are "trigonal."

Several planes occur with such regularity that, for sake of abbreviation, to represent them a letter is used instead of the symbol, for example, *R* stands for the plus rhombohedron (10$\bar{1}$1), $\bar{z}$ for the minus rhombohedron (01$\bar{1}$1), *m* for the prism (10$\bar{1}$0), *S* for the right trigonal pyramid (11$\bar{2}$1), and *x* for the right plus trapezohedron (51$\bar{6}$1) (Figs. 100–102). The construction of the right and left plus trapezohedrons

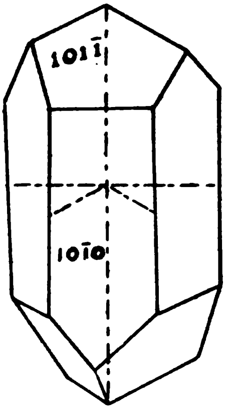


FIG. 99.—Quartz; prism and rhombohedron.

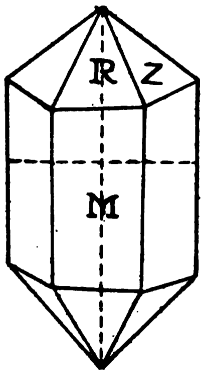


FIG. 100.—Quartz

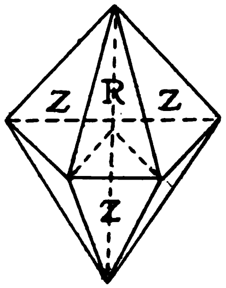


FIG. 101.—A form of quartz common at Alston Moor, England.

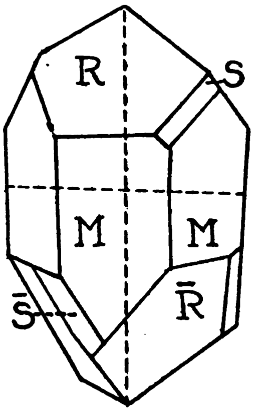


FIG. 102.—Quartz

is explained below (see Figs. 103 and 104). Rarely is a crystal terminated by a single rhombohedron, as in Figure 102. The usual termination is a combination of plus and minus rhombohedrons, *R* ($10\bar{1}1$) and *z* ($01\bar{1}1$), of different sizes. Sometimes *R* and *z* are so nearly of the same size as to resemble a unit pyramid (Fig. 101).

In some crystals, like those from Alston Moor, England, the prism planes are very small or disappear, and the result resembles a bipyramid (Fig. 101). But their trigonal character can be discovered by heating them and plunging them into water, when they cleave into imperfect rhombohedra. In some crystals the right edge between *R* and *m* is truncated by the plane *s* whose symbol is ($11\bar{2}1$) (Fig. 102). It has the direction of the diagonal pyramid, yet occurs but three times instead of six, so is recognized as a hemihedral form of the diagonal pyramid called the "right trigonal pyramid." The left trigonal pyramid appears on the left-hand side. The trigonal pyramid is often accompanied by a trapezohedral face *x* ($51\bar{6}1$). Figures 103 and 104 show right-handed and left-handed trapezohedrons. They result when the alternate upper sextants of a scalenohedron and the corresponding sextant below are developed. The trapezohedral planes are marked by the letter *x*. The right- and left-handed crystals may be distinguished in three ways: first, in a

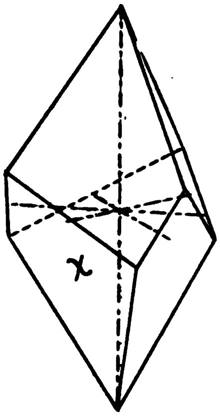


FIG. 103.—Quartz; positive left trigonal trapezohedron.

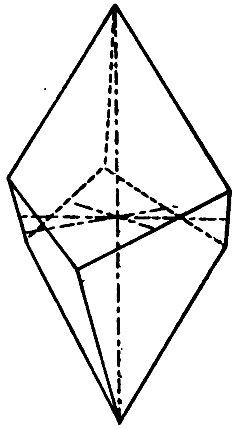


FIG. 104.—Quartz; positive right trigonal trapezohedron

PLATE XVI

Quartz, Bourg de Oisans twin, Hot Springs, Arkansas right-handed crystal the *x* plane is below the right-hand corner of the rhombohedron; second, the direction of the zone *z s x m* is that of the thread of a right-handed screw; and third, the striae on *s* are parallel to the edge *sR*.

Twinning in quartz crystals is common according to three laws: first, two crystals of the same sort, both right-handed or left-handed, may be united parallel to the *c* axis in interpenetrant twins (Fig. 105). Thus *x* may appear at each corner and *R* and *z* in the same plane. However, since *R* is usually smooth and bright, while *z* is pitted or coated, they may be distinguished from each other. The boundaries of the two interlacing crystals show a zigzag pattern. Second, right-handed and left-handed crystals interpenetrate parallel to the *c* axis and at the same time parallel to the diagonal prism $(11\bar{2}0)$. In this case twinning is betrayed by the *x* and *z* faces (Fig. 106). This is called the Brazil twin. Figure 107 shows two right juxtaposed Brazil twins. Third, Bourg de Oisans in Dauphiny (France) has long been noted for fine quartz crystals twinned in the manner shown in Figure 108 (Nos. 3307, 3308, and 3315). Recently Japan has furnished the museums of the world with a large number of these twins. They are united parallel to the diagonal pyramid $(11\bar{2}2)$ so that the *c* axis and the line of union form a zigzag.

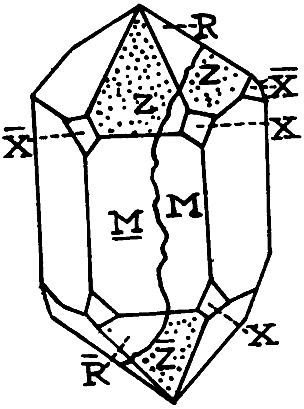


FIG. 105.—Two right-handed quartz crystals twinned parallel to *c* axis.

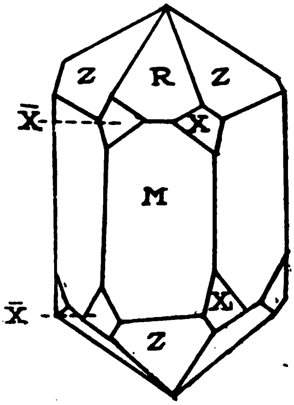


FIG. 106.—Brazil twin. Right- and left-handed quartz crystals interpenetrating.

Quartz illustrates not only the geometrical but the optical, electrical, thermal, and chemical features of crystals as well. Optical properties throw much light upon its internal structure. The connection between geometrical and electrical properties may be illustrated as follows: The three horizontal axes are polar (i.e., not symmetrical around the center), for one end of each axis emerges through a prism edge that is truncated by the planes *s* and *x*, and the other through a prism lacking these planes. Since the horizontal axes are polar, they exhibit pyro-electric polarity. Finely powdered red lead and sulphur are sifted through a piece of cloth, thus becoming electrified by friction. The red lead is positive, the sulphur negative. When they touch the heated quartz crystal, the *s* and *x* faces become negatively electrified on cooling, i.e., attract the red lead.

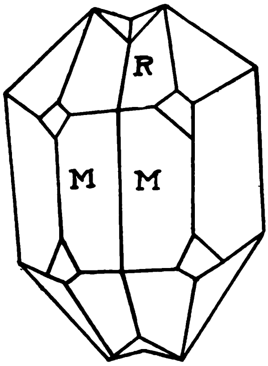


FIG. 107.—Brazil twin. Two right-handed crystals juxtaposed.

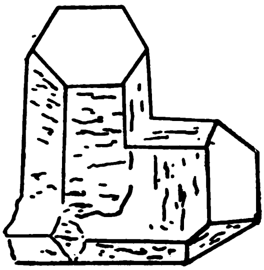


FIG. 108.—Quartz twinned on $(11\bar{2}2)$. Bourg de Oisans twin.

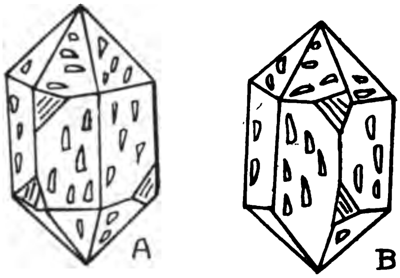


FIG. 109.—Quartz etched with hydrofluoric acid; A, left-handed; B, right-handed.

The action of caustic alkalies or hydrofluoric acid in nature or in the laboratory produces different effects on different planes, and thus the right-handed and left-handed nature of the crystals can be made evident (Fig. 109). The etching shows that the forms are related to each other as are a right and left glove, and hence they are said to be entantiomorphous.

The manner of crystal growth is shown by some specimens of quartz which within the transparent outer crystal have different layers of cloudy material forming outlines of the planes at different stages of the crystal's development. This is called "ghost quartz." "Capped quartz" has an inner kernel separated from the outer by a layer of clay or other substance which permits them to be taken apart. "Twisted quartz," while seeming to consist of a single warped crystal, in reality is composed of many individuals, each turned through a small angle so as to produce a spiral effect. Quartz is practically lacking in cleavage. Only by heating and plunging in cold water can rough rhombohedrons be obtained.

Intergrowths of right- and left-handed quartz break with a wavy surface, producing "ripple fracture," while the ordinary fracture is conchoidal.

As might be expected in a mineral so abundant and so varied in its surroundings and mode of formation, quartz exhibits great variety in form and appearance.

Rock crystal, or mountain crystal, as it was called by indefatigable collectors who sought fine specimens in the mountain fastnesses of Switzerland and the Tyrol, is a clear, transparent variety well marked in crystallization. It was formed in non-resistant rocks like clay and sandstone, or in cavities in igneous or metamorphic rocks, which afforded it opportunity to develop its own planes (see Nos. 1772 to 1779, 3896, etc.). Crystals of remarkable size have been found in the Alps, Brazil, Japan, and Madagascar. A crystal twenty-five feet in circumference was found in Madagascar. A famous cave in the Berner Oberland in Switzerland yielded five hundred tons of quartz crystals. Herkimer County, New York, is noted for its beautiful, transparent crystals. Little Rock, Arkansas, has annually furnished countless souvenirs of this kind to the tourists in that region (Nos. 473, 1775, etc.). Multitudes of geodes found at Warsaw in Hancock County, Illinois, varying in size from a hazelnut to nodules a foot or more in diameter are lined with clear quartz crystals. There is hardly a state in the United States in which fine quartz crystals have not been found.

Clear crystals have long been used for ornaments. Beautiful transparent globes as much as six inches in diameter have been cut from quartz found in Japan.

Inclosures of foreign substances may add to the beauty of the mineral. Crystals from Herkimer County, New York, often inclose anthracite flakes. Spangles of mica and of hematite produce the shimmer seen in aventurine quartz. Fibrous actinolite, asbestos, or rutile needles produce beautiful effects. Silky fibers of asbestos or of quartz replacing them give a peculiar band of color to the opalescent quartz called "cat's eye" (a name more properly applied to a variety of chrysoberyl). The golden yellow crocidolite from South Africa owes its beauty to this cause. Cavities shaped like a quartz crystal and containing water or liquid carbon dioxide are often seen.


FIG. 110.—Airy's spiral in right-handed crystal.

There are several varieties based on color: milk quartz (No. 1773) is white and opaque, morion (No. 4645) is black, smoky quartz (No. 3312) brown. Morion and smoky quartz, abundant in the Alps, are colored by a hydrocarbon which disappears upon heating. When cut into gems smoky quartz is called "cairngorm." A clear yellow quartz also colored by hydrocarbon is named citrine. Prase (No. 3225) is green from needles of actinolite. Rose quartz abundant in the Black Hills is pale red from solution of salts of titanium or manganese (Nos. 1681, 3323, 4513). Amethyst, a violet quartz, has long been one of the most popular of semiprecious stones (Nos. 4458, 588, 589, 3319, etc.). Its color is thought to be due to manganese, though upon heating to a temperature of 250° it changes to yellow. The color is often irregularly distributed, white, opaque layers alternating with transparent violet and brown layers (Plate XVII). Microscopic examination shows alternating layers of right- and left-handed lamellae. Where the right and left layers are mingled, converging light produces lines known as "Airy's spirals" (Fig. 110). The interpenetration of right- and left-handed layers produces roughly striated surfaces. The more strongly colored parts are "biaxial," that is, they have two directions in which light is not doubly refracted.

PLATE XVII

Amethyst, Thunder Bay, Lake Superior

Upon heating, the biaxial character disappears, showing that it, as well as the color, is due to easily destructible material. Beautiful violet specimens are found in Brazil, Ceylon, the Urals, Colorado, and north of Lake Superior. By some authors all quartz showing Airy's spirals is called amethyst, whatever the color.

Quartz quite commonly replaces organic substances, producing such objects of permanent beauty as silicified wood; or fills cavities formerly occupied by fluorite, calcite, barite, etc., assuming the shape of these minerals, thus producing pseudomorphs. A cube of quartz may be a pseudomorph after fluorite; fibrous quartz, a pseudomorph of fibrous gypsum; cellular quartz, the capping of calcite crystals later dissolved by water. Quartz is the great repairing agent of nature, since it so commonly cements crevices in rock layers and microscopic fissures in minerals.

SUMMARY

Quartz.—SiO_2; Si=46.7 per cent, O=52.3 per cent. Hexagonal; symmetry, trigonal holoaxial (quartz class). $a:c=1:1.1$. $m=(10\bar{1}0)$, $R=(10\bar{1}1)$, $z=(01\bar{1}1)$, $s=(11\bar{2}1)$, $x=(51\bar{6}1)$. Twinned on m $(10\bar{1}0)$ or $(11\bar{2}2)$. Massive, cleavage parallel R very imperfect; brittle; fracture conchoidal.

Hardness=7; gravity=2.65. Colorless; vitreous; transparent, $\omega=1.544$. Uniaxial; double refraction, positive weak; rotary polarization, strong.

Infusible before blowpipe; insoluble in acid.

Ubiquitous.

Chalcedony

Chalcedony is identical with quartz in chemical composition and in many physical properties, but differs in several respects. First, it never shows crystal planes but occurs in translucent or opaque botryoidal, reniform, or stalactitic masses composed of microscopic fibers. Second, the fibers composing it are optically biaxial. Quartz is uniaxial. The refractive index and fusing-point of chalcedony differ from those of quartz.

Chalcedony is waxy or greasy in luster, and somewhat splintery in fracture. It is much more soluble in potassium hydrate than is quartz. It is deposited from aqueous solution, and is found in veins or other cavities in various kinds of rocks. Usually it has banded structure and shows a great variety of colors. The banding is due to alternation of different-colored layers of chalcedony, quartz, and opal.

There are many varieties. The translucent, waxy, cream-colored, slightly banded variety is chalcedony proper. The red variety is called carnelian; the brownish-red, sard; the leek-green, plasma; the apple-green, chrysoprase (No. 3324); chalcedony with blood-red spots of jasper, heliotrope (No. 3329). Agate (Nos. 496–99, etc.) is composed of successive bands of chalcedony, carnelian, jasper (No. 568), smoky quartz, amethyst, etc., that have been laid down in the lining of a cavity, the outer band being formed first and the others successively until the cavity has been more or less filled. Usually the last stages permit of the formation of good quartz crystals. The fineness of some of the layers is a cause of wonder, and as the cavities often have no visible outlet, the manner in which the silicon reached its resting-place is enigmatical unless it be explained as being due to the solidification of colloidal silica. Sometimes the solution has deposited curvilinear layers first, and later parallel bands perfectly horizontal (No. 496). Such deposits are prized for cameo cutting. The figure is cut in one layer and the background in a layer of different color. When the layers are black and white, the material is called onyx. When red or brown, sardonyx. In moss agate (Nos. 4398 and 1851), banding is inconspicuous, but dendritic inclusions of chlorite, manganese oxide, and other substances occur. Flint (No. 3330) is a translucent to gray, brown, or nearly black chalcedony consisting largely of the remains of diatoms, sponges, and other marine organisms. The best variety is found in the chalk cliffs of England. Hornstone, as its name implies, resembles horn in color and in streaked appearance. It is more brittle, splintery, and soluble than flint, and less pure. Chert is still farther removed from flint in these respects. Its color is white or gray, and the impurities are calcareous and arenaceous substances. Jasper is a creamy, brown, or red chalcedony containing ferruginous, calcareous, or arenaceous substances as impurities.

These last four-named varieties border very closely upon rock species because of their impurities. A final step is represented by granular to massive silica, which occurs in large bodies and forms the rock called quartzite.

PLATE XVIII

Moss agate, India

SUMMARY

Chalcedony.—SiO_2; Si = 46.7 per cent, O = 53.3 per cent. Cryptocrystalline, apparently amorphous, concretionary, botryoidal, stalactitic, arborescent. Brittle; fracture conchoidal.

Hardness = 7; gravity = 2.6. Waxy, yellow, red, brown, translucent to opaque; optically biaxial, thus differing from quartz, which is uniaxial.

Infusible; insoluble.

Ubiquitous.

Opal

Opal differs from quartz and chalcedony in constitution, since water forms a part of its molecule (SiO_2 and H_2O). When water occurs in quartz it is mechanically, not chemically, included and is given off with a cracking noise (decrepitation) when the quartz is heated above the boiling-point (100° C.). In opal it is chemically combined in definite proportion, constituting most commonly about 10 per cent of the mass. At the moment of solidification a molecule of silica attracts one or more molecules of water, called the water of constitution, in distinction to mechanically included water. It is held scarcely more firmly than are the different molecules which constitute water itself, and is given off upon heating to 100° C.

Opal differs from quartz not only in composition but in physical characteristics also. It lacks crystal form, lines cavities with layers which on their free sides are botryoidal, reniform, or stalactitic, is softer and lighter than quartz, has a greasy luster, and is completely soluble in hot potassium hydrate.

Of the several varieties, the most important is precious opal (Nos. 3741 and 4725), which is highly prized for gems in spite of its opacity, low refraction, and moderate hardness. Its beauty depends upon the wonderful play of colors which the thin films composing it cause by their difference in refractive index.

For centuries near Czerwenitza, Hungary, beautiful yellow, red, green, and blue opals have been found disseminated through an altered trachyte. Similar rock near Queretaro, Mexico (No. 3334), furnishes a fiery red opal without much play of color, the so-called fire opal. Blue and green opals of great beauty are obtained from nodules of brown jaspery limonite in Queensland (No. 3741). At all these localities opals of various other shades also are found.

A perfectly transparent colorless and glassy opal found in botryoidal masses is called hyalite. Because of strain due to the solidification of the original jelly mass, it often shows double refraction. Siliceous sinter is fibrous, stalactitic, porous, or powdery opal deposited by hot waters in Yellowstone Park, Iceland, and New Zealand. Its structure is influenced by the algae which live in the water, just as blades of grass determine the form of ice deposited on them by winter's rain. The shapes of the sinter or geyserite are often fantastic and beautiful.

SUMMARY

Opal.—$SiO_2 \cdot H_2O$. Amorphous; brittle; fracture conchoidal.

Hardness = 6; gravity = 2. Colorless, white, red, brown, yellow, green, blue. Vitreous.

Infusible; yields water; soluble in potassium hydrate.

Hungary, Bohemia, Australia, Mexico, Idaho, Montana.

A. THE MONOXIDES

Minerals composed of an equal number of atoms of a bivalent metal and of oxygen are called monoxides. The two leading examples are cuprite and zincite.

Cuprite

Cuprite (Cu_2O), or "red copper ore," contains the largest per cent of copper (88.8 per cent) of any mineral except native copper. It occurs in well-formed crystals which exhibit the cube (100), octahedron (111), dodecahedron (110), trapezohedron (211), and trisoctahedron (221). A typical crystal is shown in Figure 111. Granular aggregates and dense masses are common. Fresh surfaces of cuprite have a shining red appearance like proustite, but the streak is brownish red, while that of proustite is scarlet. Cuprite is the harder of the two minerals. It is found in mineral veins where chalcocite and chalcopyrite have been subject to oxidizing agencies. Hence many veins

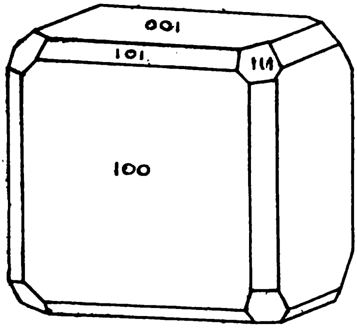


FIG. 111.—Cuprite

which above the water line contain cuprite are composed of sulphides, chalcocite, chalcopyrite, etc., below that line. Cuprite is often coated with malachite, a green copper carbonate, and at times the change extends throughout the crystal without destroying the external form. There are three varieties of cuprite: first, the ordinary crystallized form described above; second, "chalcotrichite"—"plush copper ore," consisting of slender fibers as fine as a hair, elongated in the direction of a cube edge or a cube diagonal; third, "tile ore," a brick-red, earthy mixture of cuprite and limonite.

SUMMARY

Cuprite.—Cu_2O; Cu = 88.8 per cent, O = 11.2 per cent. Regular (111), (100), (110); brittle; fracture uneven.

Hardness = 3.5; gravity = 6. Cochineal red; streak brownish-red. Metallic, adamantine; translucent; refraction very strong, $\omega = 2.85$.

Fusible; soluble in strong hydrochloric acid.

In Cordilleran states hydrochloric acid.

Zincite

In Sussex County, New Jersey, zincite (ZnO) occurs in quantities sufficient to make it a profitable source of zinc (Nos. 314, 315, 524, 747). It is of brownish or deep red color, and has a characteristic orange-yellow streak. It is usually massive, but when crystals are found they are in the hexagonal system and "hemimorphic" or "polar," since their planes are not symmetrically arranged around the center (Fig. 112). Some specimens of zincite contain as much as 7 per cent of manganese oxide (MnO), which is present in solid solution as an isomorphous mixture. That it is a solid solution is suggested by the fact that with increase of the amount of manganese the mineral becomes more yellow.

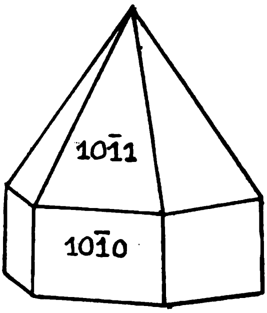


FIG. 112.—Zincite

SUMMARY

Zincite.—ZnO; Zn = 80.3 per cent, O = 19.7 per cent. Hexagonal. Symmetry, dihexagonal polar. Cleavage, perfect (0001), (10$\bar{1}$0). Brittle; fracture subconchoidal.

Hardness=4; gravity=5.6. Blood red, streak orange; luster, subadamantine; translucent; double refraction positive.

Infusible; soluble in hydrochloric acid.

New Jersey.

B. THE SESQUIOXIDES

Minerals having three atoms of oxygen to two of another element, usually a metal, are called sesquioxides. As examples we select corundum and hematite.

Corundum

Since very early in human history corundum (Al_2O_3) has been recognized and used by man. The words sapphire and ruby occur in literature two thousand years old. Sapphire is blue corundum and ruby the red variety. Ordinary corundum, being non-transparent and unattractive in color, did not early arrest attention. When cleaved, its fragments resemble feldspar, one of the most abundant of minerals, and hence would not be easily recognized. Though the name corundum is an old Hindu word, the mineral was first brought from China to Europe, and was first analyzed by a German, Klaproth, in 1787.

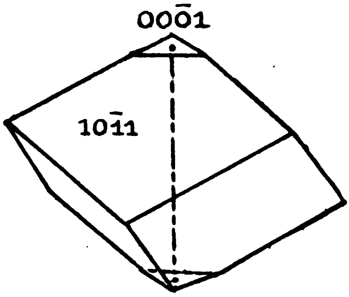


FIG. 113.—Corundum

A third variety of corundum, emery, is granular and dark in color because mixed with iron oxides such as magnetite. The name "emery" is of Greek origin, and some of the isles of Greece, especially Naxos, were long the chief source. The ancient lapidaries used it for grinding and polishing, and today its use is very extensive, although pure corundum is preferable, being superior to emery in hardness.

Sapphire, ruby, ordinary corundum, and emery differ only in purity of chemical composition, color, and in structure. Emery is the least pure, is opaque, and occurs only in grains. Corundum and the transparent varieties crystallize in good hexagonal crystals of rhombohedral symmetry (calcite class). While the sapphire and ruby are rare, corundum is abundant and may best be taken as the representative of the species. Figure 113 shows a common and typical form. It is composed of a rhombohedron truncated with a basal plane. In such a crystal it is evident that there are three planes of symmetry intersecting in the *c* axis, and that if the mineral were revolved around this axis the planes would repeat themselves three times during a complete revolution. Thus the *c* axis is an axis of trigonal symmetry. The three horizontal axes are axes of binary symmetry.

More common than the simple crystals are those composed of rhombohedrons *R* (1011), dihexagonal pyramids $(24\bar{2}3)$, diagonal prisms $(11\bar{2}0)$, and base $(00\bar{0}1)$ (Fig. 114).

Repetition of dihexagonal pyramid planes of different inclination to the *c* axis produces undulating prisms and rounded crystals. Often twinning lamellae parallel to the rhombohedron $(10\bar{1}1)$ cause striations on the basal plane and divide the crystal into sextants (Fig. 115). When the basal plane is polished, these striations reflect the light in such a manner as to produce a beautiful six-rayed star ("asterism").

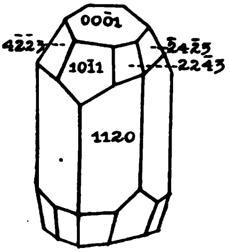


Fig. 114.—Corundum

Fig. 115.—Corundum with twinning lamellae parallel to *R*.

The largest amount of corundum has been found as water-worn pebbles, which, though rounded, usually retain their crystal shape because of their great hardness. Coarse pieces and granular masses intergrown with mica are also characteristic. In the Boston Society Natural History Museum is a group of large corundum crystals weighing several hundred pounds.

True cleavage is wanting, but there is a lamellar separation parallel to *R* and the base, due to layers of twin crystals.

Vitreous luster is characteristic. Few minerals have as great variety of color. Colorless examples are rare. When the transparent or translucent varieties are red, they are called ruby. If of the shade known as "pigeon blood," they are more highly prized than any other gem. When deep blue to lilac in color, they are called sapphire; yellow to brown, oriental topaz; green, oriental emerald; purple, oriental amethyst—a good example of the common tendency to call one object by the name of another in order to enhance its value—a tendency which should be resisted. The color is due to oxides of iron or chromium. Sapphire exposed to action of radium bromide assumes successively green, light-yellow, and dark-yellow tints, while ruby develops in succession shades of violet, blue, green, and yellow. They regain their original color upon heating.

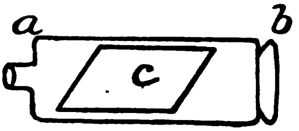


FIG. 116.—Cross-section of dichroscope.

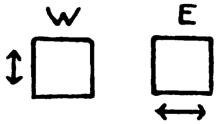


FIG. 117.—Direction of vibration of two rays of light passing through calcite prism.

In corundum (as in other transparent minerals not belonging to the regular system) the color depends upon the direction in which light passes through the crystal. Hence false gems can be readily separated from genuine ones. The mineral needs only to be examined through a dichroscope (δις, "two," χρῶμα, "color") (Fig. 116), an instrument consisting of a metal tube three inches long fitted with a weak lens at the end *a* to be held to the eye and having a small square opening at the end *b* against which the mineral to be examined is held. In the tube is a cleavage rhomb *c* of calcite ($CaCO_3$), a transparent mineral which has the power of dividing a ray of entering light into two rays that vibrate in planes at right angles to each other and consequently make a single point appear double (Plate XXI). Such a thickness of calcite is chosen as to make the square opening appear like two openings side by side. The transmitted light vibrates in the direction indicated by the arrows in Figure 117. One ray of light is called the ordinary (ω) and the other the extraordinary (ϵ).

When a piece of colored glass is placed on the square opening, both images have the same color. If a ruby is placed on the opening, the ordinary ray (ω) looks deep red, while the extraordinary (ϵ) is violet red. A sapphire appears deep blue for the ordinary ray (ω) and greenish blue for the extraordinary (ϵ) (Figs. 118 and 119).

Rubies and sapphires are found in granite, basalt, gneiss, mica and chlorite schist, granular limestone and dolomite, and in gravels derived from them. The finest sapphires have been obtained in Ceylon, the most valuable rubies in Burma. Montana and North Carolina furnish valuable sapphires, rubies, corundum, and emery.

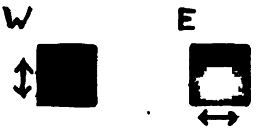


FIG. 118.—Ruby

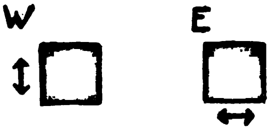


FIG. 119.—Sapphire

The examples shown come from widely distributed localities: rubies from Burma (No. 3339), sapphires from Kashmir (No. 3341) and from Queensland (No. 3340), corundum from North Carolina (No. 3342) and New Jersey (Nos. 506 and 519), emery from Massachusetts (No. 1254).

SUMMARY

Corundum.—Al_2O_3; Al = 52.9 per cent, O = 47.1 per cent. Hexagonal, symmetry rhombohedral (calcite class). $a:c = 1:1.363$. R (1011), $(24\bar{2}3)$, $(11\bar{2}0)$. Parting or pseudo-cleavage; brittle; fracture conchoidal.

Hardness = 9; gravity = 4. Many colors, vitreous, transparent, dichroic, refraction strong, $\omega = 1.768$. Double refraction, negative weak. $\omega - \epsilon = 0.008$.

Infusible; insoluble.

North Carolina, Montana, Idaho, India.

Hematite

Of all minerals in the mineral kingdom, none is more important from a human standpoint than hematite (Fe_2O_3), inasmuch as it is the mineral which furnishes the greatest quantity of iron—a metal upon which modern civilization is founded and which may be said to furnish a standard of development of a people.

In appearance hematite varies greatly with its physical condition. When well crystallized it is metallic, black, 6.5 in hardness and 5 in specific gravity. When earthy and friable it is submetallic, red, soft, and of low specific gravity.

Hematite is isomorphous with corundum, that is, it has the identical shape, though it is a different chemical substance. The best crystals are found in igneous rocks. The island of Elba has for many years furnished beautiful crystals which show the same rhombohedral symmetry already studied in corundum.

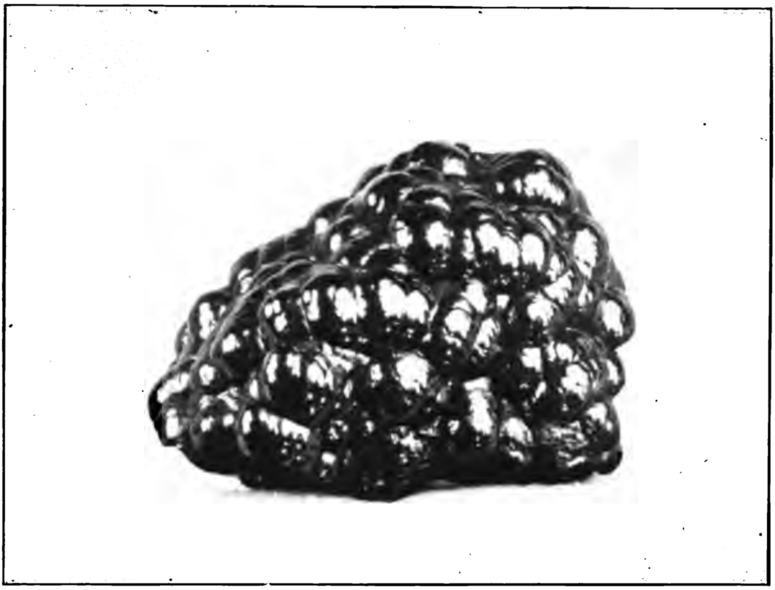
The rhombohedron *R* $(10\bar{1}1)$ occurs alone (Fig. 120) or combined with a negative flat rhombohedron $-\frac{1}{2}R$ $(01\bar{1}2)$. Rounded crystals (Fig. 121) composed of a flat rhombohedron $\frac{1}{4}R$ $(10\bar{1}4)$, the ordinary rhombohedron *R* $(10\bar{1}1)$, and the bipyramid $(22\bar{4}3)$ are characteristic. Tabular crystals composed of a broad basal plane (0001), truncating short rhombohedrons *R* $(10\bar{1}1)$, and secondary prism planes (1120) often twinned parallel to a prism plane are common (Fig. 122). They are often so grouped as to form rosettes, "iron roses."

FIG. 120.—Model of a rhombohedron $(10\bar{1}1) = R$.

Individual crystals of minute size occurring in myriads sometimes constitute great masses of ore and form the variety called micaceous hematite. The fine scales of this variety of hematite are usually imperfectly cemented so that they easily rub off and give a false impression of the hardness of the mineral.

When heated in a reducing flame, the mineral loses its red color and becomes magnetic but does not melt. The electrical conductivity of hematite has been accurately measured and is found to be two times as great in the vertical as in the horizontal direction of the crystal. Hematite is one of nature's most universal paints. It colors the rocks red and brown and yellow as it varies in amount and in its degree of oxidation. About 6 per cent of the

PLATE XIX



a, Botryoidal hematite, Cumberland, England

b, Limonite, Hardin County, Illinois

earth's crust is iron and a large part of iron is in the form of hematite. Illinois has no workable deposits, but the mineral occurs in flakes, incrustations, or red ochreous balls, or as coloring matter in all parts of the state and in massive micaceous or compact pieces in the drift.

In many parts of the world granular hematite (No. 1581) forms such extensive deposits as to furnish the largest source of iron. Well-crystallized lustrous hematite is capable of receiving a high polish and reflects the light as does a looking-glass, and hence has been called "specularite" (Nos. 3894 and 3895). The fibrous and columnar varieties are composed of individual threads or pencils more or less parallel and ending in rounded grapelike (botryoidal) (No. 3343) or kidney-shaped (reniform) surfaces and exhibiting curvilamillar markings in various places (No. 3345). Botryoidal masses break up into conical forms known as "pencil ore." Masses that are earthy and soft enough to adhere to the fingers like graphite, and usually bright red in color, suggested a name for the mineral (hematite, "bloodstone") to Theophrastus three hundred years before Christ (Nos. 343, 608, and 4496). Thin flakes such as may be seen in microscopic slides appear blood red in transmitted light, just as the powder does in ordinary light.

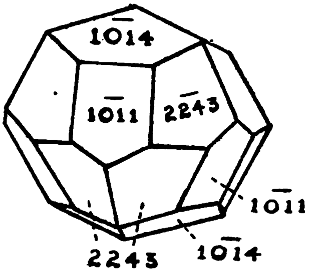


FIG. 121.—Hematite

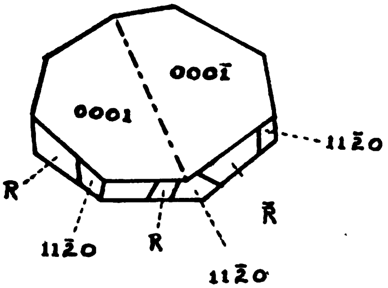


FIG. 122.—Tabular hematite crystal twinned parallel to the prism.

The great deposits of hematite in Michigan, Minnesota, Wisconsin, and Alabama make it possible for the United States to lead the world in the production of iron.

SUMMARY

Hematite.—Fe_2O_3; Fe = 70 per cent, O = 30 per cent. Hexagonal; symmetry dihexagonal, alternating (calcite class). $a:c = 1.3656$. R $(10\bar{1}1)$, $-\frac{1}{2}R$ $(01\bar{1}2)$, $\frac{1}{4}R$ $(10\bar{1}4)$, (1120), $(22\bar{4}3)$, (0001). Cleavage (parting) parallel R and (0001) imperfect; brittle; fracture uneven.

Hardness = 6; gravity = 5.2. Iron black to blood red; streak brownish red or purple; metallic; in thinnest pieces translucent and red.

Infusible alone before blowpipe; powder difficultly soluble in concentrated hydrochloric acid.

Elba, Switzerland, New York to Alabama, Minnesota, Wisconsin, and Missouri.

C. HYDRATED SESQUIOXIDES

Three minerals may be chosen to represent this group. They are:

Manganite	$Mn_2O_3 \cdot H_2O$
Goethite	$Fe_2O_3 \cdot H_2O$
Limonite	$2Fe_2O_3 \cdot 3H_2O$

Manganite

From a mineralogical point of view manganite ($Mn_2O_3 \cdot H_2O$) is of more importance than pyrolusite, though not so commercially, since pyrolusite and another manganese oxide, psilomelane, are mined in great quantities, while manganite is comparatively rare. Manganite is well defined in its physical and chemical characteristics. It occurs in steel gray to black, moderately hard (hardness, 4), orthorhombic prisms, which are usually grouped in bundles and striated vertically. The prisms end in basal planes and are striated hori-

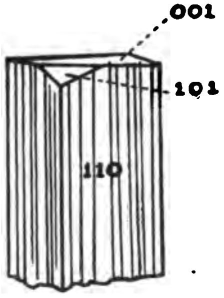


FIG. 123.—Manganite

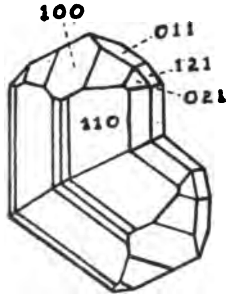


FIG. 124.—Manganite twinned parallel to $(01\bar{1})$.

zontally (Fig. 123). The customary planes are (210), (110), (120), (010), (111), (101), (011), and (021). Twins parallel to (011) are common (Fig. 124). Fibrous, radiated, and granular forms are representative (No. 3356).

Manganite is formed by deposition of manganese oxide in many springs and often replaces other minerals, assuming their forms, i.e., becoming a pseudomorph. For example, at Ilfeld, Germany, manganite (No. 3357) replaces calcite, and since the calcite has been deposited from an aqueous solution it is natural to conclude that manganite has a like origin. On the other hand, manganite changes into pyrolusite by loss of water. The process which occurs in nature is imitated by slow heating of manganite with free access of air. Pyrolusite is often found with a manganite core, showing that the process is but partially completed.

SUMMARY

Manganite.—$Mn_2O_3 \cdot H_2O$; $Mn_2O_3 = 89.7$ per cent, $H_2O = 10.3$ per cent. Orthorhombic. $a:b:c = 0.844:1:0.545$; (001), (111), (011), (101), (110), (010), (210), (120), (021); twinning parallel (011); cleavage parallel (010) perfect; brittle; fracture uneven.

Hardness=4; gravity=4.4. Steel gray; streak reddish black; submetallic; opaque.

Infusible; soluble in hydrochloric acid with evolution of chlorine.

Hartz Mountains, Michigan, Colorado.

Goethite

Goethite ($Fe_2O_3 \cdot H_2O$), named in honor of the poet Goethe, who was interested in mineralogy as well as in other natural sciences, is an iron hydrate occurring in lustrous brown or black orthorhombic prisms terminated with pyramids (No. 547).

The usual planes (Fig. 125) are (110), (210), (010), (111), (011), and rarely (001). Prism planes are often striated. Columnar forms and capillary crystals radially grouped are common. The last are called "needle iron stone." Columnar and capillary crystals bunched together in radiated and concentric masses which end in rounded surfaces are said to be "reniform." Goethite also occurs in thin red scales composed of (100), (010), (401), (011) (Fig. 116). Multitudes of these fine scales attached on one side produce a mass with velvety luster. Because of their color they are called "ruby mica," and in the finest scales are transparent, reddish yellow, and under the microscope dichroic, i.e., exhibit two different colors when the light traversing them is allowed to vibrate first in one and then in another direction through a dichroscope (see p. 96). Thus are they easily distinguished from scales of hematite, which are monochroic. Goethite crystals are common alteration products in secondary cavities, and give rise to a bronze sheen and opalescent tint. When goethite is heated it gives off water, becomes red, and changes to hematite.

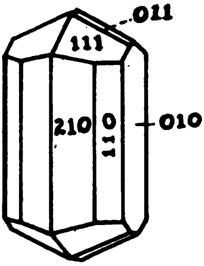


FIG. 125.—Goethite

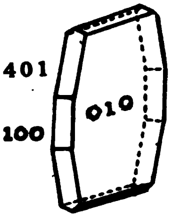


FIG. 126.—Goethite

Further heating with some reducing agent makes it black and magnetic, and heating continued until all the oxygen is removed produces pure iron. Goethite is much less abundant than either hematite or magnetite, but is a common associate of these and other iron ores in veins. Bohemia, Cornwall, Connecticut, the Lake Superior region, and Colorado yield the best crystals.

SUMMARY

Goethite.—$Fe_2O_3 \cdot H_2O$; $Fe_2O_3 = 89.9$ per cent, $H_2O = 10.1$ per cent. Orthorhombic. $a:b:c = 0.913:1:0.607$; (110), (210), (011), (111), (001), (401), (010), (100). Cleavage parallel (010) perfect; brittle; fracture uneven.

Hardness = 5; gravity = 4. Brown to black; translucent; double refraction positive; dichroic.

Fusible with difficulty to magnetic bead; soluble in hydrochloric acid.

Bohemia, Cornwall, Connecticut, Michigan, Colorado.

Limonite

Much more common than goethite is the fibrous, dense, or earthy iron hydrate, limonite ($2Fe_2O_3 \cdot 3H_2O$) named from λειμών, the Greek for a moist grassy place, since it is found as a brownish-yellow deposit in bogs. It causes the iridescent slime seen in sluggish streams and pools, replacing the decaying vegetable matter. The rusting of iron is simply a change to limonite. There are several varieties founded upon form, origin, and condition of the mineral in deposits. First, there is the fibrous, radial, curvilaminar limonite, often with black glazed (No. 1881) or opalescent lustrous surface (No. 3359), lining cavities and geodes, and hanging in stalactites in caves (Nos. 2571 and 244); second, dense compact limonite (No. 298), in veins where it has been deposited by circulating waters which have gathered it from the surrounding decomposing rocks; third, extensive beds formed by waters circulating above ground and emptying into ponds. These beds are often oölitic (No. 1747), i.e., composed of myriads of small grains, among which are found fragments of algae, foraminifera, bryozoans, etc. Such deposits are analogous to the fourth variety—bog iron ore, forming today in swamps and making granular, nodular, concretionary, earthy, or sandy masses. On the bottom of many lakes is a black mud from which small grains of limonite are separating. Measurements made in Sweden show that deposits six inches thick have been formed in twenty years. The fifth variety consists of grains as large as a pea (pisolitic). The grains often show concentric structure and fill clefts in limestone and are cemented together in clumps. Sixth, constantly associated with the denser limonite and other iron ores is a yellowish-brown, soft, porous mass called yellow ochre. It is porous because it is a remnant left after the dissolution of other materials.

That limonite is a secondary mineral derived from such minerals as siderite and also from pyrite, hematite, and magnetite, is evident because the form of the original crystal is often retained—the rhombohedrons of siderite, cubes of pyrite, octahedrons of magnetite, and hexagonal plates of hematite. Different stages of the process show different proportions of the original crystals still unaffected. All the steps of the transition from original to derived material can be traced.

The brown streak of limonite, its inferior hardness and weight, and the presence of water distinguish it from hematite. It is harder and lighter than the crystallized goethite and contains more water.

Because of the ease with which limonite fuses, it was probably the first mineral to be used by man as a source of iron.

SUMMARY

Limonite.—$2Fe_2O_3 \cdot 3H_2O$; $Fe_2O_3 = 88.5$ per cent, $H_2O = 14.5$ per cent. Amorphous, fibrous, concentric, dense, earthy.

Hardness = 5.5; gravity = 3.8. Dark brown; streak yellow brown; submetallic; opaque.

Fusible to magnetic bead; soluble in hydrochloric acid.

Scotland, Sweden, Connecticut, New York, Pennsylvania, Alabama, Ohio, Illinois.

D. ALUMINITES, FERRITES, MANGANITES, CHROMITES

The chief minerals of this group, all of which crystallize in the regular system with the octahedron as a common form, are

Spinel	$MgO \cdot Al_2O_3$
Manganite	$FeO \cdot Fe_2O_3$
Franklinite	$(Fe,Zn,Mn)O \cdot (Fe,Mn)_2O_3$
Chromite	$FeO \cdot Cr_2O_3$

Spinel

Spinel is a mineral useful as a gem because of its beauty and hardness. The minute quantities of various elements which replace a part of the Mg or Al in the typical formula $MgO \cdot Al_2O_3$ produce different colors. For example, the dark green to black opaque spinel (ceylonite) contains Fe. The yellowish- or greenish-brown variety (picotite) contains Fe and Cr, and the grass-green variety (chlorspinel) contains Fe and Cu. But the typical spinel approaching most nearly the formula $MgO \cdot Al_2O_3$ is of a beautiful clear red color, generally transparent, and called precious spinel. The purest red is called ruby spinel; the orange red, rubicelle; and the violet, the almandine spinel.

From earliest times precious spinel was prized as a gem, but was not distinguished from ruby until Romé de l'Isle studied it (1783), though these minerals differ in crystal form, cleavage, optical properties, hardness, and density. The specific gravity of spinel is 3.5, while that of ruby is 4; spinel is only 8 in hardness, while ruby is 9.

Spinel shows no pleochroism and is isotropic, i.e., it allows the light to pass through it similarly in all directions, as would be expected of a mineral crystallizing in the regular system.

In gem-bearing sands of Ceylon, Burma, and Siam, which have long been the source of precious spinel, are found small, sharp-edged octahedrons and typical spinel twins, where the octahedral face is the twinning plane (Fig. 127). The corners of the octahedrons are often beveled by trapezohedrons and the edges by dodecahedrons, giving the crystal a rounded appearance. Dark-colored varieties occur in abundance at Vesuvius, in New York, New Jersey, and North Carolina.

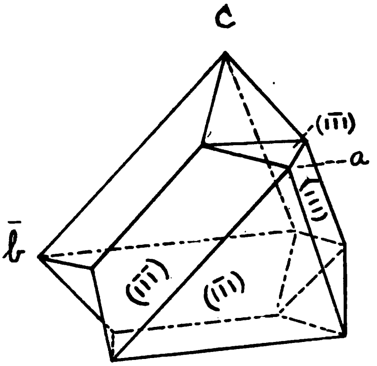


FIG. 127.—Spinel twin

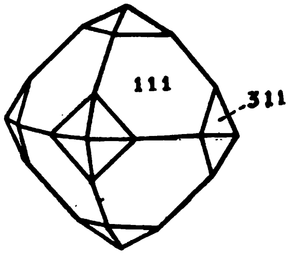


FIG. 128.—Spinel

SUMMARY

Spinel.—$MgO \cdot Al_2O_3$; $MgO = 28.2$ per cent, $Al_2O_3 = 71.9$ per cent. Regular; holosymmetric; (111). Cleavage imperfect parallel (111); brittle; fracture conchoidal.

Hardness = 6; gravity = 3.5. Red, yellow, green, black; streak white; luster vitreous; transparent; refraction high, $n = 1.715$.

Infusible; soluble with difficulty in sulphuric acid.

Burma, Ceylon, Appalachian region.

Magnetite

The third mineral in importance as a source of iron is magnetite, which derived its name, according to Pliny, from the shepherd Magnes, who found his iron-pointed staff attracted by the mineral while he was wandering over Mount Ida. It is the most magnetic of all minerals, sometimes possessing polarity and attracting particles of iron to itself (loadstone) (No. 334). Usually it is simply itself attracted by a magnet. Because of its magnetism it is easily separated from the sands of the ocean or lake or the streams in which it is found in abundance. In various sedimentary deposits in igneous and in metamorphic rocks it occurs as grains, granules, and masses.

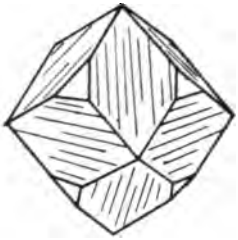


FIG. 129.—Magnetite

Crystals of magnetite show most commonly octahedral (No. 3346) and dodecahedral forms in which the dodecahedron is striated parallel to the octahedral edges (No. 548), because of oscillatory combination (Fig. 129). The magnetism and the black streak of magnetite distinguish it from hematite.

SUMMARY

Magnetite.—$FeO \cdot Fe_2O_3$; $FeO = 31$ per cent; $Fe_2O_3 = 69$ per cent. Regular; holosymmetric; (111), parting, parallel (111); brittle; fracture uneven.

Hardness = 6; gravity = 5.8. Black; streak black; metallic; opaque. Magnetic, sometimes polar.

Fusible with difficulty; powder easily soluble in hydrochloric acid.

Scandinavia, Urals, Altai Mountains, New York, Pennsylvania, New Mexico, North Carolina.

Franklinite

Franklinite closely resembles magnetite in form, color, hardness, and weight, but has a browner streak, is more commonly rounded on its octahedral edges, and is but slightly magnetic. Its usual association with the red zinc oxide (No. 3348), zincite, renders its determination by physical means less difficult, but chemical test (search for a zinc incrustation on charcoal or the amethystine color of manganese in the borax bead) is necessary for its accurate determination.

The mineral receives its name from Franklin Furnace, New Jersey, where it has been found in great quantities.

SUMMARY

Franklinite.—$(Fe,Zn,Mn)O.(Fe,Mn)_2O_3$. Regular; holosymmetric; (111); rounded grains. Resembles magnetite in physical properties, but is slightly magnetic and browner in streak.

Hardness = 6; gravity = 5.
Infusible, soluble in hydrochloric acid.
Franklin Furnace, New Jersey.

Chromite

Chromite resembles magnetite and franklinite in form and color (No. 543), but is slightly softer (hardness 5.3) and lighter (gravity, 4.5). The best means of identifying it is to test for the green color which it gives to a cold borax bead.

Chromite owes its importance to the fact that it furnishes practically all the chromium used in the arts and manufactures. Chromium compounds are used to color porcelains and enamels green, and to dye calicoes, etc. Their most important use of late years, however, has been to harden steel. Before the world-war nearly a million dollars' worth of chromite was imported annually, a few thousand dollars' worth only being produced in this country. As a result of government investigation and encouragement production of domestic chromite was greatly increased. It is found in rocks consisting chiefly of olivine and serpentine.

SUMMARY

Chromite.—$FeO \cdot Cr_2O_3$; $FeO = 32$ per cent, $Cr_2O_3 = 68$ per cent. Regular; holosymmetric (111); granular, massive; uneven; fracture brittle.

Hardness = 5.5; gravity = 4.5. Black, yellowish red in very thin sections; dark brown.

Infusible; insoluble in acids, decomposing when fused with sodium sulphate.

New Caledonia, Bohemia.

E. DIOXIDES

The minerals in this group contain two atoms of oxygen to one of the basic element. Those which most merit attention are:

Cassiterite	SnO_2
Rutile	TiO_2
Pyrolusite	MnO_2

Cassiterite

This mineral, the only important source of tin, has been known since earliest times and was used by the ancients to make bronze. In color it is usually dark brown or black. It is hard (hardness, 6.5), heavy (gravity, 7), insoluble, and infusible, and is usually in the form of rounded grains and pebbles or short stout crystals.

The color of cassiterite depends upon impurities such as iron oxide (Fe_2O_3), tantalum oxide (Ta_2O_5), etc. Pure varieties, which are rare, are colorless, transparent, and lustrous, and, were they a little harder, would be much prized for gems. In Mexico yellowish varieties are found, and Australia has yielded some fine red specimens; but most cassiterite is black.

Owing to its hardness, weight, and stability, it occurs in stream deposits as "stream-tin" and has been successfully mined in the Malay Peninsula, Australia, the Black Hills, and California. In primary deposits it is persistently associated with certain acidic igneous rocks, such as granites and pigmatites, where it has crystallized in short, stout tetragonal crystals, usually twinned. Simple crystals (Fig. 130) composed of (111), (110), (100), (101) are rarer than the twin forms which are so characteristic. The twinning plane is parallel (011), as shown in Figure 131. Prism planes are usually striated parallel to *c*. Basal planes are almost unknown. Slender prisms, having acute, ditetragonal pyramids such as (321) in addition to the more usual pyramids, occur rarely and are called "needle tin." Some of the massive varieties have a radiated fibrous structure, are arranged in curvilaminar layers of different shades, and in a botryoidal surface lack the luster of the ordinary crystal. Being remarkably dull and wooden, they are called "wood tin." Little brown-banded spherical nodules with the same fibrous structure are called "toad's

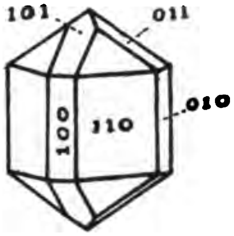


FIG. 130.—Cassiterite

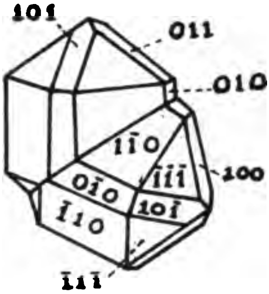


FIG. 131.—Cassiterite twinned on $(01\bar{1})$

eye tin" in Cornwall, which has long been the most productive tin region.

The minerals associated with cassiterite suggest its origin. They are commonly apatite, fluorite, zinnwaldite, topaz, and tourmaline—all of which contain fluorine and lead to the thought that vapors containing fluorine were influential in the deposition of cassiterite. Daubree produced cassiterite artificially by the action of steam on tin fluoride. But cassiterite is produced in two other ways also. Violet-colored simple crystals have been made in tin works by the oxidation of metallic tin, and cassiterite has been found replacing organic remains and cementing nodules, as would be the case were it deposited from solution, or from vapors.

The chief uses of cassiterite are as a source of tin for plating and the manufacture of alloys.

SUMMARY

Cassiterite.—SnO_2; $Sn = 78.6$ per cent, $O = 21.4$ per cent. Tetragonal; holosymmetric. $a:c = 1:0.672$. (111), (100), (110), (101), (210), (321); twinned on (101); cleavage parallel (100) imperfect; brittle; fracture sub-conchoidal.

Hardness = 6.5; gravity = 7. Brown or black; streak gray; adamantine; translucent; $\omega = 1.997$; double refraction positive; $\epsilon - \omega = 0.097$.

Insoluble; with soda on charcoal yields tin.

Cornwall, Malay Peninsula, Wyoming, and Dakota.

Rutile

Rutile (TiO_2) is a source of titanium, an element used for giving a yellow color to glass, for hardening steel, and for various chemical purposes. Its hardness is the same as that of cassiterite (6.5), and its color and form are very similar, but it is redder (*rutilus*, Latin for "red") and has a yellowish-brown streak instead of a grayish streak. It is only 4.3 in specific gravity and cleaves readily to (100) and (110), hence is easily distinguished from cassiterite. It occurs in stout crystals (Nos. 3354 and 3355), in acicular and twin crystals, and in masses (No. 3197). The stout crystals (Fig. 132), nearly duplicating those of cassiterite, consist of the following planes: (100), (110), (011), all of which may be vertically striated, and (111) and (101).

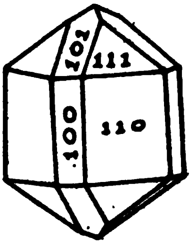


FIG. 132.—Rutile

Twinning parallel to (011) is very common (Fig. 133) and the twins are often repeated six or eight times till they form a complete ring with the different individuals inclined to each other in a zigzag with angles of 65° 35″ (Fig. 134).

Acicular crystals varying from the finest threads to needles and blades of some thickness often penetrate other minerals such as quartz.

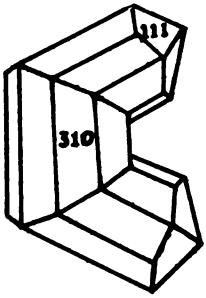


FIG. 133.—Rutile triplet twinned on (011).

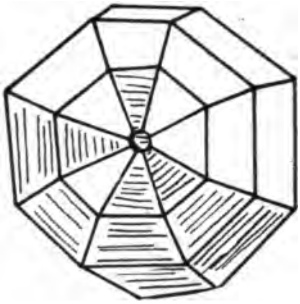


FIG. 134.—Rutile octet twinned on (011).

The beautiful yellowish-red or brown fibers in quartz are called *fleches d'amour*. In some groups the needles cross each other at the twinning angle and form a reticulated skeletal plate called "sagenite" (=net).

SUMMARY

Rutile.—TiO_2; Ti=60 per cent, O=40 per cent. Tetragonal; holosymmetric. $a:c=1:0.644$. (100), (110), (310), (111), (101); twinned on (101); cleavage, parallel (100), (110); brittle; fracture uneven.

Hardness=6.5; gravity=4.3. Reddish brown; streak yellowish brown; metallic; adamantine; translucent; $\omega=2.616$; double refraction positive strong, $\epsilon-\omega=0.287$.

Infusible; insoluble.

Switzerland, Virginia, North Carolina, Florida, Arkansas, Alaska.

Pyrolusite

Pyrolusite (MnO_2) is an amorphous, black, soft (hardness, 2) mineral used in glass manufacture to clear the glass from green and brown colors (Nos. 541 and 1838). Because of its usefulness in this respect it has received its name (πῦρ, "fire"; λύειν, "to wash"). Large quantities are employed also as a flux in iron manufacture.

It has no crystal form of its own, but borrows its form of manganite, from which it is derived by the loss of water. Brazil and Russia before the war supplied the United States with the greatest part of the manganese ore needed. About one million tons of ore came from Russia in 1913. In 1916 more than that amount was produced in the United States.

Summary

Pyrolusite.—MnO_2; $Mn=63.2$ per cent, $O=36.8$ per cent. Pseudomorph after manganite, showing radiated fibrous structure, but usually massive, earthy, soiling the fingers.

Hardness = 2; gravity = 5. Gray to black; streak black.

Infusible; soluble in warm hydrochloric acid.

Minnesota, Arkansas, California, Virginia, Russia, Brazil.

CLASS VI. CARBONATES

CALCITE GROUP

Calcite Group	Hexagonal
Calcite	$CaCO_3$
Dolomite	$CaMg(CO_3)_2$
Magnesite	$MgCO_3$
Siderite	$FeCO_3$
Rhodochrosite	$MnCO_3$
Smithsonite	$ZnCO_3$

Calcite

Calcite is one of the most important and interesting minerals in the world, both because of its beauty and abundance, and because of its usefulness from a scientific and practical standpoint. The history of calcite is the history of mineralogy. In abundance it is surpassed by quartz alone. Its crystals occur in such profusion, variety, and beauty as easily to have attracted the attention of mineralogists and to have continually furnished them with material for study. This study has led to important results. About the time that the Dane, Steno, noted the regularity of the angles on quartz and announced the law of the constancy of angle, a countryman of his, Erasmus Bartholinus (1670), was working with the splendid calcite crystals then recently discovered in Iceland (No. 3832); and in his book *Experimenta Crystalli Islandici* described the remarkable cleavage and the double refraction which calcite shows more satisfactorily than does any other mineral.

Twenty years later the Hollander Huygens, famous for his undulatory theory of light, extending Bartholinus' study of calcite, was able to formulate the laws of double refraction—the laws of a phenomenon which could not be explained by the corpuscular theory of Newton. For many years following, while discussion of the corpuscular and wave theories of light was at its height, calcite was carefully studied by the advocates of both theories. As the result of such study Malus (1808) discovered the polarization of light. Today calcite is much used in optical researches because of its effect on light, being employed for "nicol prisms" in microscopes, both for purely scientific and for commercial purposes.

erals in
cause of
history
rpassed
ty, and
sts and
This
Dane,
ounced
rasmus
rystals
s book
eavage
ctorily

or his
alcite,
s of a
heory
e cor-
e was
result
light.
effect
h for

PLATE XX

Calcite, Webb City, Missouri; twinned on $(10\bar{1}0)$

PLATE XXI

a, Calcite, "dog-tooth spar," Joplin, Missouri

b, Calcite, "Iceland spar," showing double refraction

No mineral shows more planes and combinations of planes than does calcite. More than two hundred forms and seven hundred combinations have been described. There are four distinct habits of crystallization—rhombohedral, scalenohedral, prismatic, and tabular. The fundamental form is the rhombohedron, *R* (10$\bar{1}$1), (Fig. 135), in which the mineral always cleaves, and so readily that it is difficult to produce a fracture in any other direction (Nos. 3460 and 3832). As an independent form this plane is rare but is found on crystals from near Bologna, Italy, and is a predominant form on the calcite from Iceland ("Iceland spar"). The obtuse rhombohedron, $-\frac{1}{2}R$ (01$\bar{1}$2) (Fig. 139), is common. Figure 137 represents another common acute rhombohedron. The scalenohedron which furnishes the so-called "dog tooth spar" (Fig. 138) (Nos. 3446, 3458, etc.) is a form of frequent occurrence. Prism planes also appear (No. 3450), modified usually with rhombohedron planes as in Figure 139, where the rhombohedron is negative, $-\frac{1}{2}R$. If the prisms are short and a basal plane is present, tabular crystals similar to Figure 140 result. Sometimes they are as thin as paper and grouped parallel to one another so as to give the effect of cleavage which is peculiar to slate, hence the variety is called "slate spar." Scalenohedrons are usually modified by rhombohedrons (Fig. 141).

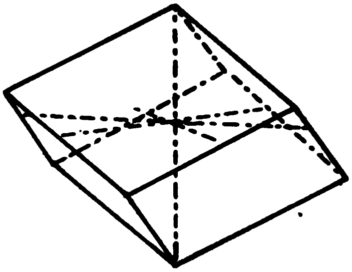


FIG. 135.—Calcite. Positive rhombohedron (10$\bar{1}$1) = *R*; the cleavage rhombohedron.

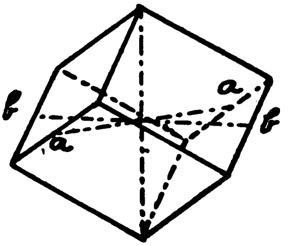


FIG. 136.—Calcite. Negative rhombohedron (01$\bar{1}$1) = $-R$.

All these forms agree in having three planes of symmetry, which are diagonal to the lateral crystallographic axes, and intersect in the vertical axis *c*, the axis of trigonal symmetry. Such symmetry is so typical as to have been named after calcite the "calcite class."

There are four types of twins: (1) A common type is that in which two crystals are united by juxtaposition on the basal plane. Figure 142 shows a rhombohedron and Figure 143 a scalenohedron twinned according to this law. If the crystals overlap, filling the re-entering angles, cleavage lines will disclose the twinning. (2) More common than the foregoing is that type whose twinning plane is $-\frac{1}{2}R$ $(01\bar{1}2)$. In this case the cleavage planes of the two individuals are parallel. Figure 144 shows a juxtaposed twin of this sort characteristic of crystals from Guanajuato, Mexico. Twinning lamellae

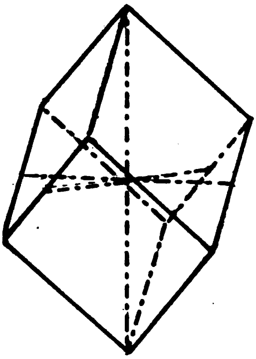


FIG. 137.—Calcite. Negative acute rhombohedron $(02\bar{2}1) = -2R$.

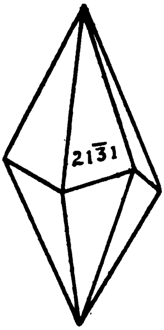


FIG. 138.—Calcite, scalenohedron.

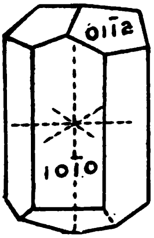


FIG. 139.—Calcite, prism and negative obtuse rhombohedron.

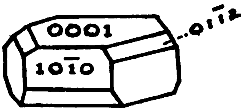


FIG. 140.—Calcite, showing prism, negative obtuse rhombohedron, and base.

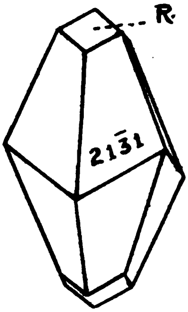


FIG. 141.—Calcite; combination of scalenohedron and rhombohedron.

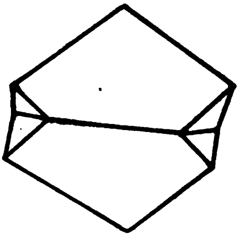


FIG. 142.—Calcite. Rhombohedron twinned on (0001).

in
ne.
on
he

e,
e
.

PLATE XXII

Calcite, Joplin, Missouri; $(21\bar{3}1)$ and $(31\bar{4}5)$

PLATE XXIII

Calcite scalenohedron, Rossie, St. Lawrence County, New York

parallel to $-\frac{1}{2}R$ have been commonly produced in calcite by pressure, and in thin sections under the microscope are so characteristic as to furnish the best means of distinguishing the mineral. They well illustrate secondary twinning such as may be artificially produced in calcite and is especially pronounced in "Iceland spar." (3) The type of twinning parallel to the cleavage rhombohedron R, though rare, is shown in scalenohedrons and prisms (Figs. 145 and 146). In these twins one cleavage plane only is parallel to the two individuals.

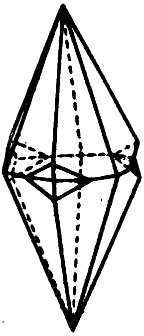


FIG. 143.—Calcite scalenohedron twinned parallel to (0001).

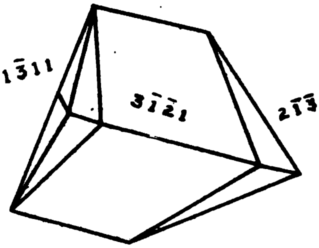


FIG. 144.—Calcite scalenohedron twinned parallel to $(01\bar{1}2) = -\frac{1}{2}R$.

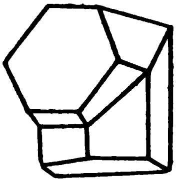


FIG. 145.—Calcite prism twinned parallel to R.

(4) The type where the twinning plane is the acute negative rhombohedron $(02\bar{2}1)$ produces forms which closely resemble those of the second class, but here the cleavage planes of the different individuals are not parallel (Fig. 147).

Some calcite crystals exhibit asterism, i.e., when a candle flame is viewed through them it appears as a radiating star of light. This is due to systems of hollow tubes parallel to each other in three directions, and is produced where the "gliding surfaces" of the negative rhombohedron $-\frac{1}{2}R$ intersect each other.

Calcite is useful for nicol prisms because the ordinary ray while passing through it is so greatly refracted ($\omega = 1.658$). The extraordinary ray is allowed to pass through the prism, being but slightly affected by the Canada balsam whose index is nearly that of the extraordinary ray. (For balsam $\epsilon = 1.536$.)

A microscopic section of calcite rotated above the polarizer when the analyzer is removed shows high relief if the ordinary ray is allowed to pass through, and relief so low as to be almost invisible when the extraordinary ray passes through.

When calcium carbonate crystallizes from aqueous solution in veins or other cavities, it forms the ordinary variety of calcite. If it is deposited from springs or streams by evaporation in a more or less granular condition it forms travertine, calc tufa, stalactites, and stalagmites. If it is composed of fragments or organic remains cemented by calcareous or other cements, it forms chalk, oölite, and limestone. If the limestone has been metamorphosed by heat and pressure so as to become crystallized, it forms marble. Among some of the localities the following are famous because of the abundance and beauty of their crystallized varieties. In Iceland near Eskifjördhr a cavity 36 feet long, 15 feet wide, and 10 feet high in dolomite rock was found filled with clear crystallized calcite. The prevailing forms were rhombohedrons $(10\bar{1}1)$ with edges beveled by scalenohedrons $(21\bar{3}1)$ and $(31\bar{4}5)$, and scalenohedrons terminated by $(10\bar{1}1)$ or $(31\bar{4}5)$. Their surfaces were often corroded or coated with other minerals such as stilbite.

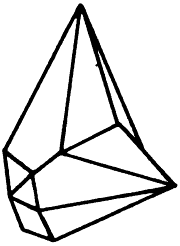


FIG. 146.—Calcite scalenohedron twinned parallel to *R*.

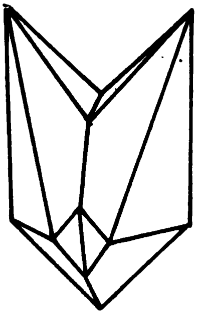


FIG. 147.—Calcite scalenohedron twinned parallel to $(02\bar{2}1)$.

In England the lead, iron, and fluorite mines of Derbyshire, Dunham, and Cumberland (Nos. 3450, 3451, and 3452) have furnished fine crystals which now ornament museums in all parts of the world. Many beautiful crystals come from the Hartz Mountains. They are

PLATE XXIV

a, Calcite, Joplin, Missouri; $(21\bar{3}1)$ and $(31\bar{4}5)$

b, Quartz geode with large flat rhombohedral crystals, St. Francisville, Missouri commonly prismatic planes and tabular forms. The silver mines of Guanajuato, Mexico, have furnished twin crystals of great beauty and variety. Among many famous localities in the United States may be mentioned St. Lawrence County, New York (No. 4657); the Lake Superior copper mines with their complex crystals which often contain spangles and wires of copper; and the Wisconsin, Illinois (Nos. 698 and 699), and Missouri (No. 3459, etc.) lead and zinc mines with their rhombohedrons and scalenohedrons. The geodes of Keokuk contain numerous large flat crystals (Nos. 686, 691, 672). At Joplin, Missouri, many large, beautiful, honey-yellow scalenohedrons $(21\bar{3}1)$ terminated by rhombohedrons R $(10\bar{1}1)$ and the striated $-\frac{1}{2}R$ have been found. The acute terminal edges of these scalenohedrons $(21\bar{3}1)$ are often replaced by striated and rounded faces (Nos. 3886, 3899, 3890, also Plate XXIII).

SUMMARY

Calcite.—$CaCO_3$; $CaO=56$ per cent, $CO_2=44$ per cent. Hexagonal; symmetry dihexagonal alternating (calcite class); $a:c=1:0.854$. R, $-\frac{1}{2}R$, $4R$; twinned on (0001), $(01\bar{1}2)$, $(10\bar{1}1)$, $(02\bar{2}1)$. Cleavage parallel R perfect; brittle; fracture conchoidal.

Hardness=3; gravity=2.72. Colorless; vitreous; transparent; refraction strong, $\omega=1.658$; double refraction very strong, positive, $\omega-\epsilon=0.172$.

Infusible; soluble with effervescence in cold hydrochloric acid, diluted to one-third strength.

Ubiquitous.

Dolomite

Dolomite can be distinguished from calcite, which it very closely resembles, from the fact that it is harder (hardness, 3.5), heavier (gravity, 2.85), and does not effervesce in cold hydrochloric acid diluted to one-third strength, except when finely powdered. Though strongly resembling each other in crystal form, calcite and dolomite differ in this respect, that while calcite has dihexagonal alternating symmetry, dolomite has hexagonal alternating symmetry (dioptase class), i.e., it lacks all planes of symmetry, and the vertical axis is an axis of trigonal symmetry. This becomes evident when the two minerals are etched with acid and when their axes of elasticity are measured. If rhombohedrons of calcite and dolomite are placed in dilute hydrochloric acid, upon the surface appear depressions which show the symmetry of the crystals. The depressions on calcite (Fig. 148) indicate three planes of symmetry, since each etched figure has one line of symmetry parallel to the shorter diagonal of the rhombohedron, showing that a plane of symmetry is perpendicular to that face. A dolomite rhombohedron treated in the same manner is marked with pits unsymmetrical in outline (Fig. 149), indicating that there is no plane of symmetry perpendicular to the rhombohedron. The figures on the three upper faces are related to each other as are a right-handed and a left-handed glove, the lower ones appearing as if they were reflections of the upper (enantiomorphous). This indicates that the crystal has one hexagonal axis of alternating symmetry, a fact which is also shown by rhombohedron planes which are sometimes developed upon the alternate edges of the usual rhombohedron.

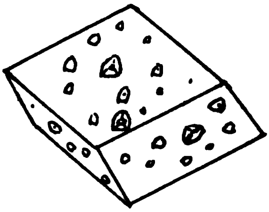


FIG. 148.—Calcite etched with dilute hydrochloric acid.

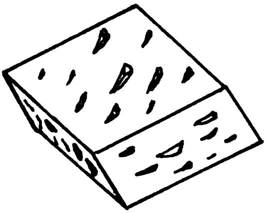


FIG. 149.—Dolomite etched with dilute hydrochloric acid.

The difference in the symmetry of calcite and dolomite is also indicated by their coefficients of elasticity. These coefficients are obtained by cutting bars of the minerals, supporting them on knife edges, applying a weight sustained by a knife edge, and measuring the amount of bending by microscopic or other means. When lines are drawn on a rhombohedral face proportional to the amount of bending and the ends connected, curves shown in Figures 150 and 151 are produced. In calcite the elasticity is symmetrically arranged parallel to the diagonal of the rhombohedron. In dolomite it is unsymmetrical. Thus etching and measuring of elasticity show that the rhombohedrons are not perpendicular to planes of symmetry in dolomite. Further, in calcite it was seen that $-\frac{1}{2}R(01\bar{1}2)$ is a glide plane, or plane of secondary twinning, as shown by the series of hollow tubes arranged parallel to this plane and appearing as fine lamellae under the microscope. The presence of this glide plane can be discovered by pressing a knife into a cleavage rhombohedron across one of the terminal edges. By the pressure the molecules are revolved 180° into a new twinning plane, so that the other lamellae are parallel to $-\frac{1}{2}R$ (Fig. 152). In dolomite $-\frac{1}{2}R$ is not a plane of secondary twinning.

Dolomite is a double salt of calcium and magnesium—a molecule of each carbonate being united to form it. If it were an isomorphous mixture of the two carbonates in molecular proportions, its crystallization would be the same as that of calcite and magnesite. However, it is different, and it would have a specific gravity of 2.843. But it is heavier (gravity, 2.85), just as would be expected, since while the double salt is forming there is a contraction of the two carbonates which increases their specific gravity.

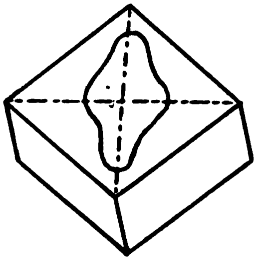


FIG. 150.—Elasticity coefficient of calcite.

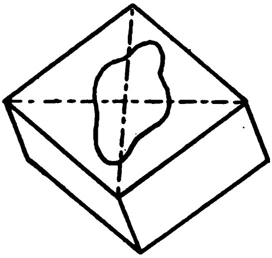


FIG. 151.—Elasticity coefficient of dolomite.

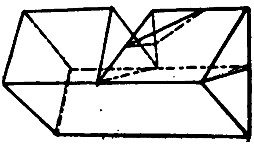


FIG. 152.—Glide planes in calcite.

Dolomite occurs in well-crystallized forms deposited from solution and in masses made of fragments of organic remains which have been more or less altered and cemented by chemicals in solution. The massive variety forms extensive beds which extend for miles over the country.

Vermont, New Jersey, and New York (No. 3217, etc.) furnish many crystals. Saddle-shaped crystals are abundant in Joplin, Missouri (No. 3464). The greater part of the limestone of Illinois is dolomitic.

SUMMARY

Dolomite.—$CaMg(CO_3)_2$; $CaO=30.4$ per cent, $MgO=21.7$ per cent, $CO_2=47.9$ per cent. Hexagonal; symmetry hexagonal alternating; $a:c=1:0.832$. $(10\bar{1}1)$; cleavage parallel $(10\bar{1}1)$ perfect; brittle; fracture conchoidal.

Hardness=3.5; gravity=2.85. Colorless, streak white; vitreous; transparent. Refraction strong, $\omega=1.682$; double refraction strong, negative, $\omega-\epsilon=0.189$.

Infusible; soluble with effervescence in warm acids.

Tyrol, Switzerland, England, Vermont, New Jersey, New York, Missouri.

Magnesite

The pure magnesium carbonate is a white brittle mineral, usually massive, granular, and earthy. It is harder than either of the two other members of the group thus far described (hardness, 4) and heavier (gravity, 3.1). Before the world-war this mineral, obtained mainly from Greece (No. 3466), furnished a large part of the magnesium needed in the arts and manufactures. Recently magnesite from Quebec, California, etc., has been used; also dolomite and the waters from which sodium chloride had been extracted.

SUMMARY

Magnesite.—$MgCO_3$; $MgO=47.6$ per cent, $CO_2=52.4$ per cent. Hexagonal; $a:c=1:0.8112$. Massive, granular, earthy; brittle; fracture sub-conchoidal. White; vitreous; silky; transparent to opaque.

Infusible; effervesces in warm hydrochloric acid. Common decomposition product of ferromagnesian silicates.

Greece, Canada, California, Washington, Maryland.

Siderite

Siderite, $FeCO_3$, which furnishes almost no iron in the United States, is an important iron ore in Germany (No. 4512), and the most important source of iron in England. When pure it occurs in brown, vitreous, translucent rhombohedrons, or in fibrous botryoidal or globular forms. The rhombohedrons are often curved and sometimes acute. Large basal planes give rise to a tabular variety which often has zonal structure caused by hexagonal bands. Being liable to oxidation, the mineral readily loses its gray color, becomes brown, and changes into limonite. The dehydration of limonite produces hematite and finally magnetite.

Among European localities, Cornwall and Freiburg are the most productive of siderite, while in the United States the Appalachian regions have furnished the largest supplies. Of recent years Ohio has been the leading producer.

SUMMARY

Siderite.—$FeCO_3$; $FeO=62.1$ per cent, $CO_2=37.9$ per cent. Hexagonal; symmetry, dihexagonal alternating; $a:c=1:0.818$. $(10\bar{1}1)$, (0001); faces curved; fibrous, globular. Cleavage parallel $(10\bar{1}1)$ perfect; brittle; fracture sub-conchoidal.

Hardness = 3.5; gravity = 3.8. Brown; vitreous, translucent. Refraction very strong, $\omega=1.878$; double refraction very strong, negative $\omega-\epsilon=0.241$.

Fuses at 4.5 to black magnetic globule. Effervesces in warm hydrochloric acid.

Cornwall, Freiburg, Ohio, Appalachians.

Rhodochrosite

Beautiful rose-pink rhombohedrons of rhodochrosite are found in, Colorado (Nos. 3471 and 3472), the Ural Mountains, and other places where solutions carrying manganese carbonates have for some cause slowly given up their burden. The reddish color of rhodochrosite easily distinguishes it from the other carbonates.

SUMMARY

Rhodochrosite.—$MnCO_3$; $MnO=61.7$ per cent, $CO_2=38,3$ per cent. Rounded $(10\bar{1}1)$, massive, compact. Cleavage parallel $(10\bar{1}1)$ perfect; brittle; fracture uneven.

Hardness = 4; gravity = 3.5. Rose red; translucent; negative.

Infusible. Effervesces in warm hydochloric acid.

Russia, Hungary, Saxony, Belgium, New Jersey, Colorado.

Smithsonite

The physical condition, that is, the form, cleavage, fracture, hardness, weight, luster, diaphaneity, and optical properties of the zinc carbonate, smithsonite, closely resemble that of the other members of the group. Smithsonite is sometimes colorless, but more usually green (No. 3751), blue, or brown from the presence of copper, iron, or other foreign substances. It is used as a zinc ore in the Mississippi Valley region, as well as in other places. In northern parts of Illinois it formerly produced upward of a thousand dollars' worth of zinc annually.

SUMMARY

Smithsonite.—$ZnCO_3$; $ZnO = 64.8$ per cent, $CO_2 = 35.2$ per cent. Usually botryoidal, reniform, granular, earthy.

Hardness = 5; gravity = 4.4. White, green, blue, brown, vitreous.

Infusible; gives zinc coating with soda on charcoal. Effervesces in warm hydrochloric acid.

Many European localities, Wisconsin, Illinois, Iowa, Missouri, Arkansas.

The calcite group furnishes one of the best illustrations of isomorphism which the mineral kingdom affords, since the carbonates of calcium, magnesium, iron, manganese, and zinc, all different chemical substances, assume practically the same form. All the members of the group are rhombohedral in form, practically identical in cleavage, very similar in hardness and gravity. All effervesce in warm hydrochloric acid. The following group, the aragonite group, all of whose members are orthorhombic, is another illustration of isomorphism.

ARAGONITE GROUP

ARAGONITE GROUP	ORTHORHOMBIC
Aragonite	$CaCO_3$
Witherite	$BaCO_3$
Strontianite	$SrCO_3$
Cerussite	$PbCO_3$

Aragonite

The orthorhombic form of calcium carbonate, named from Aragon in Spain where it was first found, is much less common than calcite. Its comparative rarity may be due to two causes: (1) to the conditions necessary for its formation; and (2) to its instability. One of the conditions necessary for its formation is that the solution from which it is deposited must be hot, whereas calcite is usually deposited from cold waters. This is shown when the two minerals are made in the laboratory and by the conditions which surround aragonite

er,
he
rn
's'

t.

ı

PLATE XXV

a, Aragonite crystals four inches in diameter, Cianciana, Sicily

b, Stalactites, Bisbee, Arizona

in the field and by its associations. Aragonite very often accompanies sulphur crystals, which are commonly deposited in volcanic regions from hot solutions. There are exceptions, such as the calcium carbonate deposited by living organisms in the shells of mollusks, which is in the form of aragonite. Further, if a calcium carbonate solution contains a minute quantity of a soluble sulphate or orthorhombic carbonate, aragonite crystals may be formed. Aragonite is less stable than calcite, readily changing its crystal form at ordinary temperature.

When one mineral changes into another of the same composition by simply altering its form, it is called a paramorph. When it changes into the form of a mineral of different composition it is called a pseudomorph. For example, a quartz crystal which assumes the cubic shape of fluorite is said to be a pseudomorph after fluorite. An aragonite crystal which takes the form of calcite is said to be a paramorph. A paramorph can be detected, for example, when an aragonite crystal is but partially paramorphosed, the inner portion being aragonite and the outer calcite. Paramorphism is possible only among minerals which exhibit dimorphism or polymorphism. Aragonite and calcite were the earliest recognized examples of dimorphism in the mineral kingdom.

Aragonite rarely occurs in simple orthorhombic crystals. It is nearly always twinned parallel to the prism in such a manner as to produce seemingly hexagonal forms. Nearly all calcium carbonate which is fibrous, stalactitic, botryoidal, or concretionary is classified as aragonite. For example, the stalactites of Mammoth Cave and other caves (Nos. 2118, 2119), the pisolites of Carlsbad and other hot springs, and the beautiful white coral-like groups from Wind Cave, South Dakota (No. 3176), and Bisbee, Arizona, are aragonite.

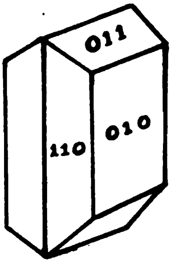


FIG. 153.—Aragonite

Aragonite can be distinguished from calcite when the crystal form is not evident by its superior hardness and weight.

Simple crystals (Fig. 153) are composed of prisms, brachypinacoids, and dome planes. Groups of crystals with predominance of acute pyramids (441), (991), and (081), (091), showing horizontal striations, are common. If three crystals such as shown in Figure 154 interpenetrate parallel to the prism plane and the re-entering angles are filled in, a form having the cross-section shown in Figure 155 and resembling a hexagonal prism is produced. Large, white, yellowish prisms of this sort are found at Girgenti and Cianciana, Sicily (No. 3902), and at the sulphur mines in Hungary. At Aragon, Spain, the crystals are corroded and are found in red ferruginous marl with gypsum and quartz. Nos. 2116 and 2120 show stalactites from Chester, Illinois; No. 2117, aragonite as fossilizing material at the same locality; Nos. 2672, 2685, examples from Rock Island; No. 3469 shows botryoidal masses from Quincy; No. 3176 from the Black Hills; Nos. 3467 and 3468 are from Fort Collins. Carlsbad, Bohemia, is also represented. No. 3902 is an unusually fine group consisting of two large crystals of interpenetrating triplets and several smaller imperfect crystals. The largest crystal measures about four inches in diameter and is two inches high.

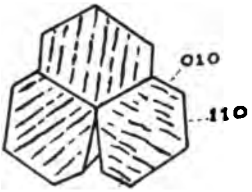


FIG. 154.—Basal section of aragonite triplet.

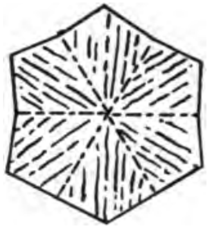


FIG. 155.—Basel section of aragonite; interpenetrant triplet.

SUMMARY

Aragonite.—$CaCO_3$; $CaO = 56$ per cent, $CO_2 = 44$ per cent. Orthorhombic. $a:b:c = 0.628:10.721$. (110), (010), (011), (001), (111); twinned on (110); cleavage (010), (110) imperfect; brittle; fracture sub-conchoidal.

Hardness $= 3.5$; gravity $= 2.9$. Colorless; vitreous; transparent; mean angle of refraction, $\beta = 1.682$, the least, $\alpha = 1.530$. Double refraction very strong, negative, i.e., difference between the greatest angle of refraction, γ, and the least, α, is 0.156.

Infusible; effervesces in hydrochloric acid.

Spain, Sicily, Cordilleran states.

Witherite

This carbonate of barium occurs in white, heavy, not very abundant crystals and masses. The crystals appear to be hexagonal pyramids (Fig. 156), but a thin section cut parallel to the base (Fig. 157) shows that the seemingly simple crystal is composed of three orthorhombic crystals, twinned parallel to prism planes and hence crossing each other at angles of 62°—the angle between the prism planes. Upon the pyramid planes are more or less prominent striations caused by the growth of a succession of different capping pyramids. The pyramid planes vary in their intercepts on the *c* axis and produce both acute and obtuse forms. In addition to well-formed crystals there are aggregates made up of acicular crystals, grouped into botryoidal and reniform shapes. Compact masses are the most characteristic form of the mineral.

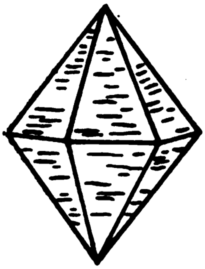


FIG. 156.—Witherite

FIG. 157.—Cross-section of witherite

The luster of the fresh crystals is greasy, but is changed when sulphur fumes or solutions coat the surface with barium sulphate, changing it into a dull white.

Witherite may be distinguished from minerals of similar appearance by the fact that it is heavy, effervesces in cold hydrochloric acid, and colors the blowpipe flame green. Great quantities are produced in two northern counties in England, where it was discovered in 1783 by the mineralogist after whom it was named, Withering, and where it has been mined for more than one hundred years. Witherite is used for medicinal and industrial purposes. Large quantities are employed in the manufacture of rat poison.

SUMMARY

Witherite.—$BaCO_3$; $BaO = 77.7$ per cent, $CO_2 = 22.3$ per cent. Orthorhombic; holosymmetric. $a:b:c = 0.603:1:0.730$. (110), (010), (011). Common form pseudohexagonal bipyramid produced by interpenetration twinning of three individuals at angles of 62°; twinning plane (110). Brittle; fracture uneven.

Hardness = 3.5; gravity = 4.3. Colorless; streak white; vitreous; translucent. Double refraction negative, weak; axial plane parallel (010); acute bisectrix perpendicular to (001). $2E = 26° 30'$.

Fusible (2); effervesces in hydrochloric acid.

Northumberland and Cumberland, England; Kentucky, Michigan.

Strontianite

Strontianite very closely resembles aragonite in color, streak, luster, and form, but differs in being heavier (gravity, 3.7) and in yielding the intense red color characteristic of strontium when heated in the blowpipe flame.

Strontianite is sometimes colorless and transparent, but more often translucent and white, green, yellow, or brown. Its fibrous, acicular, or columnar crystals are rarely well defined or terminated. They are usually vertically striated. The same kind of twinning occurs as is so common for aragonite and witherite, viz., interpenetrant triplets forming pseudohexagonal prisms or pyramids.

At Strontian on the west coast of Scotland in 1791 a mineral was found that contained a new element. The element was named strontium and the mineral strontianite.

Strontianite finds limited use as a source of red lights for fireworks and in the refining of beet sugar.

SUMMARY

Strontianite.—$SrCO_3$; $SrO = 70.1$ per cent, $CO_2 = 29.9$ per cent. Orthorhombic; holosymmetric. $a:b:c = 0.6090:1:0.7239$. (110), (010), (011); fibrous, acicular, columnar, granular; cleavage parallel (110) nearly perfect; brittle; fracture uneven.

Hardness = 3.5; gravity = 3.7. Colorless, white, green, yellow, brown. Optically negative; axial plane parallel to (100); bisectrix perpendicular to (001). $2E = 12° 17'$.

Fusible; soluble in hydrochloric acid.

Scotland, Appalachian states.

Cerussite

Cerussite, like aragonite, witherite, and strontianite, simulates crystals of the hexagonal system, while in reality its molecules arrange themselves in accordance with the laws of the orthorhombic system. Simple crystals of cerussite are more abundant than are those of witherite and strontianite. The most common habit is the form produced by pyramids, domes, short prisms, and pinacoids (Fig. 158), and the tabular crystals like those in Figure 159, in which the domes are elongated parallel to the *a* axis and the pinacoid is the predominant plane.

The commonly occurring interpenetrant twinning of three crystals parallel to prism planes produces raylike pyramids (Fig. 160).

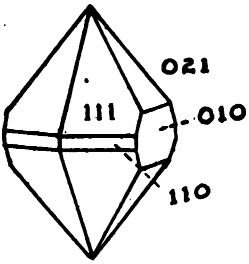


Fig. 158.—Cerussite

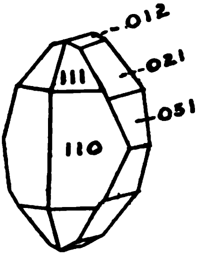


Fig. 159.—Cerussite

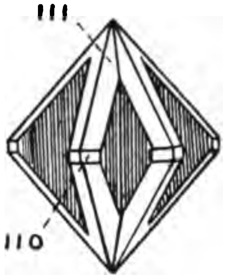


Fig. 160.—Three cerussite crystals interpenetrating parallel to prism planes.

Besides pyramids and tabular crystals, single and combined, acicular and fibrous masses are of common occurrence. All these crystals when fresh have smooth, bright, lustrous surfaces. Silky or adamantine luster is characteristic of lead minerals. The best specimens have been obtained from Bohemia, Hungary, New South Wales, and Idaho, where they are found on galena and other lead ores, from which they have resulted by the decomposition of galena.

SUMMARY

Cerussite.—$PbCO_3$; $PbO=83.5$ per cent, $CO_2=16.5$ per cent. Orthorhombic; holosymmetric; $a:b:c=0.610:1:0.723$. (110), (010), (111), (021); twinned on (110); cleavage parallel (110), (021) imperfect; brittle; fracture conchoidal.

Hardness=3.5; gravity=6.5. Colorless; streak white; adamantine; transparent; $\beta=2.076$, $\alpha=1.804$; double refraction strong, negative; $\gamma-\alpha=0.274$; axial plane (010); acute bisectrix perpendicular to (001). $2\,E=17^\circ\ 8'$

Fusible; soluble in nitric acid.

Cordilleran states.

Malachite

Malachite (μαλάχη, "mallow or willow tree") is a basic copper carbonate, which is readily recognized because of its vivid green color. Fine compact nodular masses composed of radial fibers have been found in such quantities in the Ural Mountains (No. 3407) and so rarely in other European localities that they have furnished the rulers of Russia a unique and much-prized material for gifts. In palaces and museums in all the capitals of Europe the tourist sees vases, tables, and other ornaments made of this striking green mineral. They are usually recorded as "a gift from the Czar of Russia." In many European and American localities malachite (Nos. 3405, 3406) occurs in such quantities as to furnish a useful source of copper. When crystallized under favorable conditions, in cavities, for example, it forms fine fibrous needles which build tufts as soft in appearance as velvet (velvet malachite). Radiating fibers fill winding cavities so as to look like roots of trees when exposed. The granular and earthy forms of malachite are the most abundant. Well-formed crystals are almost unknown, but acicular prisms disclose the fact that the molecules have so arranged themselves as to produce forms characteristic of the monoclinic system.

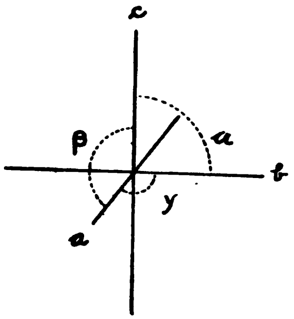


FIG. 161.—Axes of monoclinic crystal.

In this system the molecular structure is represented by three axes of unequal length (Fig. 161). The angle β which the a axis makes with the c axis is greater then 90°. The α and γ angles are right angles. Planes constructed upon these axes produce figures having a plane of symmetry parallel to c and a, and an axis of symmetry which is the *c* axis. The forms which constitute the system are analogous to those of the orthorhombic system. They are pyramids (111), prisms (110), orthopinacoids (straight pinacoids) (100), clinopinacoids (inclined pinacoids) (010), orthodomes (101), and clinodomes (011). As in the orthorhombic system, closed forms are obtained by combinations of two or more kinds of planes in all cases except that of the pyramid (Fig. 162). In Figure 163 orthodomes are united with clinodomes to produce a complete form. Figure 164 shows a combination of prism and base.

Malachite does not well illustrate the crystallography of the monoclinic system. To understand its crystals it is necessary to resort to the microscope. Indeed, with any transparent mineral employment of optical means of investigation contributes greatly to the knowledge of its crystallography. Sections of minerals cut at various angles are cemented with Canada balsam to pieces of glass and ground till thin enough (about one-hundredth of an inch in thickness) to permit light to pass through them. Examined under the microscope, first with the light vibrating in all directions, then with light made to vibrate in but one direction by means of a calcite prism ("Nicol prism"), and studied with light passing through the mineral with parallel rays and then with converging rays, the crystal structure becomes clear. Such an examination of malachite reveals the fact that there are two directions in which light is not doubly refracted, that these directions are in the plane (axial plane) parallel

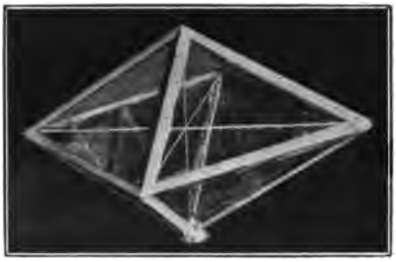


FIG. 162.—Monoclinic bipyramid

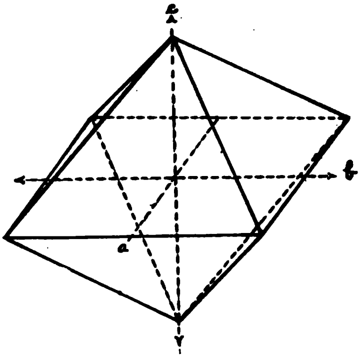


FIG. 163.—Orthodomes and clinodomes

to the clinopinacoid, that they form an angle of nearly 90° with each other (2 $E=89°\ 18'$), that the line which divides this angle (called the acute bisectrix) forms an angle of 32° 50′ with the *c* axis, and

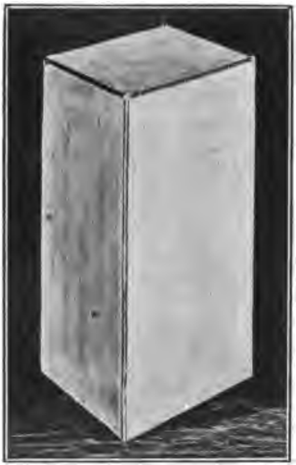


FIG. 164.—Model of prism and basal plane.

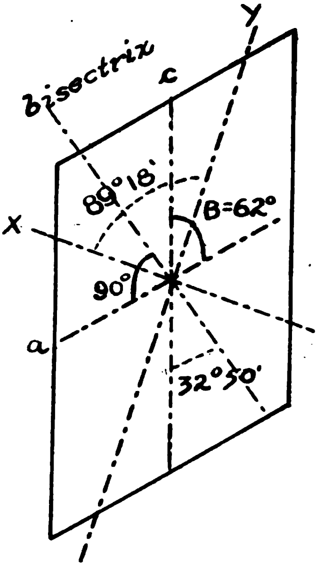


FIG. 165.—Malachite section parallel to (010).

that the angle between *c* and *a*, the β angle, is 61° 50′. A cross-section of a malachite crystal (Fig. 165) parallel to the clinopinacoid shows the relationship of these various directions.

SUMMARY

Malachite.—$CuCO_3 \cdot Cu(OH)_2$; $CuO=71.9$ per cent, $CO_2=19.9$ per cent, $H_2O=8.2$ per cent. Monoclinic; $a:b:c=0.881:1:0.401$. $\beta=61°\ 50'$. (110), (001); twinned parallel (100); cleavage (010), (001) perfect; brittle; fracture uneven.

Hardness$=3.5$; gravity$=4$. Green; adamantine; silky; dull; translucent. $\beta=1.88$; double refraction negative; $\gamma-\alpha=0.2$.

Easily fusible; soluble in hydrochloric acid.

Urals, Cordilleras.

Azurite

Azurite is another basic carbonate of copper conspicuous because of the beauty of its color, which is a deep azure blue. In composition it differs from malachite in having less copper oxide. Azurite has 69.2 per cent, malachite 71.9 per cent. Azurite by increase in water content changes to malachite, increasing about one-third in bulk, thus affording an illustration of a chemical action which would tend to rend inclosing minerals or rock. Azurite crystals partially changed into malachite are of common occurrence. Both of these minerals result from decomposition of copper sulphides, are useful ores of copper, and are found in the same localities. Azurite occurs in good monoclinic crystals in which the prism (110) and base (011) predominate, modified by pyramids (111) and domes (013) (Fig. 166). Chessy near Lyons, France, and Bisbee, Arizona (Nos. 3409, 3410), are noted for their fine crystals.

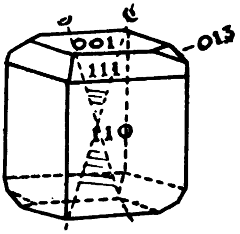


FIG. 166.—Azurite crystal, showing also position of optic axes and axial plane.

SUMMARY

Azurite.—$2CuCO_3 \cdot Cu(OH)_2$; $CuO = 69.2$ per cent, $CO_2 = 25.6$ per cent, $H_2O = 5.2$ per cent. Monoclinic; $a:b:c = 0.85:1:1.76$; $\beta = 87° 36'$. (110), (001), (111), (103); cleavage parallel (011) fair; brittle; fracture conchoidal.

Hardness = 4; gravity = 3.8. Deep to light blue; vitreous; translucent in thin pieces. Double refraction positive; $\gamma - \alpha = 0.2$. Axial plane perpendicular to (010); acute bisectrix makes an angle of 75° with a and lies in the supplementary angle to β.

Easily fusible (2); soluble in hydrochloric acid.

Urals, France, Arizona.

CLASS VII. SILICATES

The carbonates are a very important group of oxygen salts, as we have just seen, but the silicates are even more important, especially if we consider their number of species and their quantity. Their quantity is so great that they constitute nine-tenths of the mass of the earth's crust. There are several hundred species, from which we select about forty only. These forty are most worthy of our attention because of perfection of form, beauty of color, durability, utility, or abundance. Some of them are so abundant as to be the chief minerals in great mountain chains. Some are highly prized as gems, others as minerals useful for chemical and various commercial purposes. But it is as rock-forming minerals *par excellence* that they most strongly bespeak the attention. The most abundant representatives of the section are the minerals first to be considered, namely, the feldspars.

FELDSPAR GROUP

Though the word feldspar was used by the Germans as early as 1750, the minerals to which we now give that name have been distinguished for not much more than one hundred years and have been thoroughly studied only within the last seventy-five years. Today no minerals are better described and understood. Their investigation has contributed largely to the science of mineralogy. They deserve the attention which they have received, both because of their scientific and because of their commercial importance.

They afford excellent illustration of the relation of crystal structure to physical properties, such as the transmission of light and heat, and form an important feature in the classification of igneous rocks. Commercially they are of importance because of their use in manufacture and agriculture. They are the source of clay—a mineral substance valuable in soils; useful for paving and building brick, porcelain and china; and essential to the artist and artificer for modeling, to the manufacture of woolens as fuller's earth, and to the chemist and smelter as fire clay.

They are found in nearly all parts of the country, but are most characteristic of mountain regions and of areas covered by glacial drift. For this reason the southern Mississippi Valley is about the only portion of the country in which feldspar may rarely be found. All of the feldspars in Illinois are found in the drift which covers the larger part of the state. For the best specimens one turns to igneous rocks in mountain regions.

All of the feldspars are aluminium silicates of potassium, sodium, or calcium, and rarely barium. Their prevailing color is white or light shades of red; they are about 2.5 in specific gravity, 6 in hardness, and split readily in two directions. They are divided into two sections because some of them crystallize apparently in the monoclinic system and others in the triclinic system.

The most important feldspar with the monoclinic habit is orthoclase.

THE ORTHOCLASES

Orthoclase

This is a potassium feldspar ($KAlSi_3O_8$) in which a little of the potassium may be replaced by sodium. The color of orthoclase varies from colorless, glassy adularia and sanidine (No. 3477) to white, gray, yellowish, or reddish individuals (Nos. 3413 to 3415), or masses more or less opaque owing to partial conversion into kaolin.

Orthoclase is insoluble in acids without previous fusion. Pure orthoclase fuses at 5 in the scale of fusibility (about 1150° C.), but with the increase of sodium, which is probably due to an intermixture of a sodium feldspar like albite, the melting-point is lowered.

Orthoclase is the chief constituent of the granitic rocks which occur in such great masses in the Rocky Mountains, the Alps, and other mountain regions. When mingled with the quartz and mica which constitute a large part of granite, the crystal outlines of orthoclase may be undeveloped, but may still be readily recognized by the cleavage planes which are parallel to the base (001) and clinopinacoid (010) and are at right angles to each other. The quartz in granite is without cleavage and the mica cleaves in one direction only and is elastic.

When the orthoclase is in druses (cavities lined with crystals), well-developed forms like those in Figure 167 show its pronounced

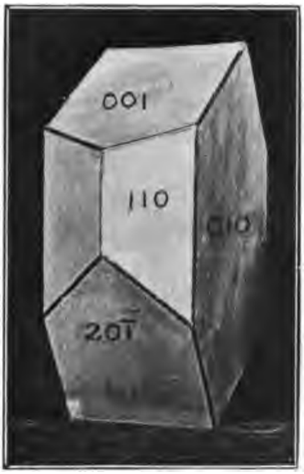


FIG. 167.—Model of an orthoclase crystal.

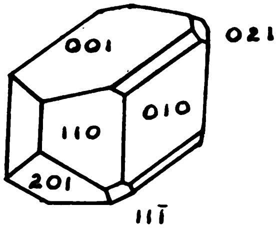


FIG. 168.—Orthoclase

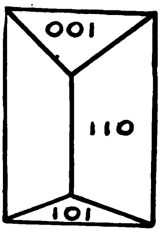


FIG. 169.—Adularia orthoclase

FIG. 170.—Model of Carlsbad twin, interpenetrating parallel (010); twinning axis *c*.

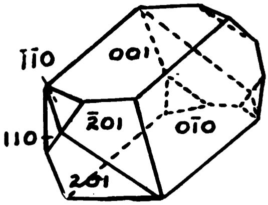


FIG. 171.—Baveno twin, composition face (021).

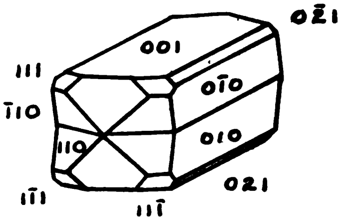


FIG. 172.—Manebach twin, composition face (001).

tendency to assume clearly marked outlines. Such crystals are found abundantly in Colorado and are composed of prisms (110), brachypinacoids (010), domes (2̇01), and basal planes (001). The dome (201) is nearly at right angles to the base. Quite similar to them in shape but usually thinner, in boardlike forms parallel to (010), is sandidine (from σανίς, "a table"), which is found as limpid glassy crystals in the feldspar blocks thrown out of Vesuvius and as large, dull-gray crystals in trachyte at the Drachenfels, Germany.

Forms less columnar but elongated in the direction of the edge between the base and clinopinacoid and having in addition pyramid planes (111) and clinodomes (021) (Fig. 168) are customary in the pink feldspar of the Baveno granite quarries.

Glassy crystals, called adularia from Adula, the old name of St. Gothard, Switzerland, where they are found in abundance, have the form shown in Figure 169. In all these crystals the cleavage parallel to (001) is most perfect, that parallel to (010) is but little inferior, while that parallel to (110), though barely evident, is important in the orientation of the crystal. When prismatic cleavage lines are placed vertically and the basal plane turned until it slants downward toward the observer, the crystal is in conventional position. The clinopinacoid is almost always vertically striated. Cleavage cracks on (001) often produce a pearly luster. The pale-blue opalescence of the Ceylon "moonstone" is due to cleavage cracks, to inclusion of feldspathic material, or to decomposition.

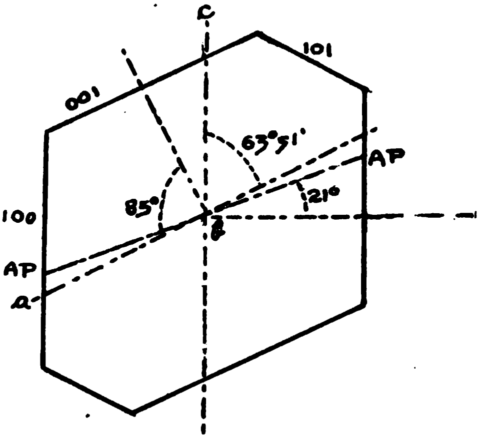


FIG. 173.—Orthoclase section parallel to (010); axial plane, angle of extinction.

Twinned crystals are as abundant as are simple forms, and the twinning follows three laws which have been named after three localities where multitudes of good specimens are found and were first studied. The localities are Carlsbad, Bohemia; Baveno, Piedmont, northwestern Italy; and Manebach, Saxe-Gotha, Germany.

Carlsbad law: Two individuals interpenetrate parallel to (010), one of them being turned around on the *c* axis until the back side is toward the front (Fig. 170). The twinning axis is *c* and the composition face is (010). If the crystal is terminated by $(\bar{1}01)$ and (001) instead of $(\bar{1}01)$ only, the two planes will be nearly in the same plane but may be distinguished, since the base is a plane of cleavage while the dome is not. Also while the base is smooth and bright, the dome may be dull.

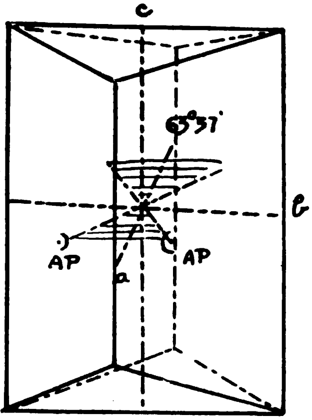


FIG. 174.—Orthoclase (adularia); axial plane.

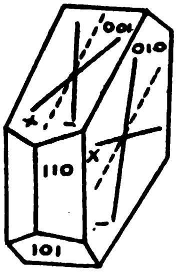


FIG. 175.—Orthoclase; positive and negative direction of extinction on (001) and (010).

Baveno law: Two individuals are united parallel to the clinodome (021) and one is revolved 180° so that the original back planes are turned toward the front. Twinning and composition plane is (021). Since the angle formed by (021) and (001) is of nearly 45° and that between (021) and (010) is the same, Baveno twins may appear to be rectangular prisms (Fig. 171). But cleavage planes will show that two basal planes (001) come together on one edge and two clinopinacoids (010) on the other. At the ends will be observed a diagonal line of union. At one end are small salient angles formed between $(\bar{2}01)$ and (201) (13°42′) and between (110) and $(\bar{1}\bar{1}0)$ (10°34′). At ed-

c.
is
c-
d
e
of
d

PLATE XXVI

a, Microcline, "Amazon Stone," Pike's Peak, Colorado

b Microcline, Pike's Peak, Colorado

the other end are re-entering angles. Baveno twins are often repeated to produce quartets.

Manebach law: Two individuals are twinned and composed on (001). The two clinopinacoids then fall in the same plane, but the end discloses the twinning (Fig. 172).

Summary

Orthoclase.—$KAlSi_3O_8$; $K_2O = 16.9$ per cent, $Al_2O_3 = 18.5$ per cent, $SiO_2 = 64.6$ per cent. Monoclinic; $a:b:c = 0.658:1:0.555$. $\beta = 116°\ 3'$. (110), (001), (010), $(10\bar{1})$, $(20\bar{1})$, (021), (111). Carlsbad law, twinning axis *c:* composition plane (010). Baveno law, twinning plane and composition plane (021). Manebach law, twinning plane and composition plane (001). Cleavage parallel (001), (010) perfect, (110) imperfect. Brittle; fracture conchoidal.

Hardness = 6; gravity = 2.5. Colorless to red; vitreous; transparent; $\beta = 1.524$; double refraction negative, weak; $\gamma - \alpha = 0.006$. Axial plane perpendicular to (010). Acute bisectrix 5°, above *a* axis on (100): extinction on (010) − 5°, on (001) 0°. $2E$ varies but usually is in the neighborhood of 120°.

Insoluble; fusible (5).

In granite, gneiss, trachyte. More common in metamorphic rocks than are plagioclases. Mountain regions, Colorado, Switzerland, Italy; confined to the drift in Illinois.

Microcline

Closely related to orthoclase and connecting it crystallographically with plagioclase is microcline. In orthoclase (ὀρθος, "straight"; κλάω, "to cleave") the basal plane and cleavage parallel to it form a right angle to the clinopinacoid plane and the cleavage parallel to it. In microcline (μικρός, "small"; κλίνειν, "to incline") these planes deviate but about 15′ to 35′ from a right angle; that is, the angle which (001) makes with (010) is generally about 89° 30′. In plagioclase (πλάγιος, "oblique"; κλάω, "to cleave") the angle between the basal plane (001) and brachypinacoid (010) is about 86°.

The chemical composition, hardness, specific gravity, and general character of microcline (No. 3418) are the same as those of orthoclase, and were it not for the inclination of the *b* axis to the *c* the two species would be classed as one. But because of their inclination microcline is a triclinic feldspar. Its crystals are generally composed of two sets of twins, one parallel to the brachypinacoid (010) and the other at right angles to it, namely, parallel to the edge formed by (001), the base, and (101), the macrodome. This produces a curious cross-hatching or grating structure best seen under the microscope when the nicols are crossed as two series of lamellae in the basal plane. It is called the "microcline structure." It would be possible for the twins which cause the cross-hatching to be so fine as to be invisible. Then the inclination of (001) to (010) might disappear, the cross-hatching become indistinguishable, and microcline then resemble orthoclase completely. For this reason some authors think that orthoclase is simply an extreme form of microcline and that all of the feldspars are triclinic.

Green varieties of microcline are called Amazon stone. Pike's Peak, Colorado (Nos. 3416, 3245, 3420, and 1251), and the Ilmen Mountains in Russia have long been reputed for fine specimens of Amazon stone which they have furnished. Museums are quite generally supplied with specimens from these localities.

SUMMARY

Microcline.—Like orthoclase, except that the *b* axis is inclined about half a degree, the basal cleavage often shows fine striations and between crossed nicols cross-hatching, and the angle of extinction on base is $+15° 30'$, while in orthoclase it is 0°.

Anorthoclase.—$(Na,K)AlSi_3O_8$. Triclinic; resembles microcline. Cross-hatching often so fine as to be scarcely visible; (201) and (110) often elongated.

In alkaline lavas (Pantellaria) and porphyries (Christiania).

Hyalophane.—$K_2BaAl_4Si_8O_{24}$. A double salt composed of two molecules of orthoclase ($KAlSi_3O_8$) and one of barium alumino-silicate ($BaAl_2Si_2O_8$). It occurs in monoclinic glassy crystals which closely resemble adularia (Fig. 174).

In dolomite in Tyrol, etc.

Of the more than threescore minerals thus far considered, but one before microcline has been found to crystallize in the triclinic system, and that one, cryolite, is so poor a representative of the system that no description of triclinic symmetry was given in that connection. But microcline, and more especially the plagioclases now about to be described, are the most important minerals constructed with triclinic symmetry.

In the triclinic system are grouped such forms as have three axes of unequal lengths crossing each other at angles not right angles.

The angle between *c* and *b* is called *α*, that between *c* and *a*, *β*, and that between *a* and *b*, *γ*, as indicated in Figure 176. Upon these axes planes are constructed which cut all three axes, pyramid planes (111); or which cut two axes and are parallel to the third, prisms (110) and domes (011), (100); or which cut one axis and are parallel to two, pinacoids (010), (100), (001). The longer of the two lateral axes is chosen as *b* and the dome and pinacoid parallel to it are the macrodome and macropinacoid. The brachydome and pinacoid are parallel to *a*. The figures produced by any one kind of plane are not closed forms. They have neither planes nor axes of symmetry but a center of symmetry only. The figures may readily be drawn by following the method employed for preceding systems. This system is the sixth and completes the crystallographic groups which embrace all crystallized minerals.

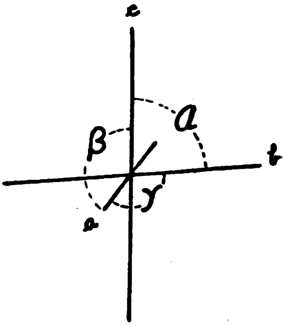


FIG. 176.—Triclinic axes of copper sulphate; no axes at right angles.

THE PLAGIOCLASES

The feldspars which exhibit between the two chief cleavage planes angles markedly different from a right angle are grouped together as plagioclases. They compose two species widely separated chemically, one being the sodium feldspar, albite ($NaAlSi_3O_8$), and the other the lime feldspar, anorthite ($CaAl_2Si_2O_8$). Between these two is a series formed by insomorphous mixtures of albite and anorthite molecules in varying proportion. If Ab represents the albite molecule and An the anorthite molecule, the typical composition of the chief varieties may be expressed as follows:

Albite	Ab
Oligoclase	Ab_3 An
Andesine	Ab An
Labradorite	Ab An_3
Bytownite	Ab An_6
Anorthite	An

In physical as well as chemical properties these six minerals form a continuous series and afford a fine illustration of the variations of optical characters with molecular constitution. They may readily be distinguished from each other by microscopic or by chemical tests.

Plagioclase strongly resembles orthoclase in crystallographic and physical properties, but may usually be recognized by the fine striations on the basal plane. These striations are due to repeated twinning of thin leaves parallel to the brachypinacoid (010).

Some plagioclases are more common than orthoclase in igneous rocks, both as constituent of the ground mass and as inclosed crystals (phenocrysts). The six different kinds are shown in their order, beginning with albite.

Albite

Albite (*albus*, "white") occurs in white masses or as crystals in cavities in igneous rocks and crystalline schists in the Appalachian (No. 3124) and Cordilleran regions and in all the mountain ranges of the world.

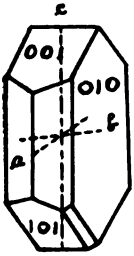


FIG. 177.—Albite

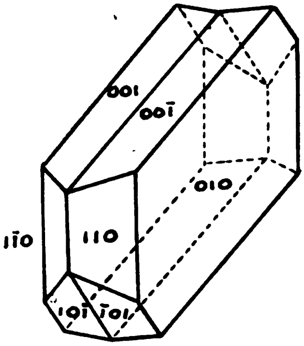


FIG. 178.—Albite twinned on (010); albite law.

The simple crystal (Fig. 177) resembles orthoclase in outline, as do also some of the twins which follow the Carlsbad, Baveno, and Manebach laws. But the most common and typical crystals are twinned according to the albite and the pericline laws.

According to the albite law the twinning plane and the composition face are (010) and the basal planes form re-entrant angles with each other (Fig. 178). The different crystals are usually thin as paper and repeated so as to produce polysynthetic twins which give rise to fine striations and pearly luster best seen on the basal plane.

According to the pericline law (Περικλινῆς, "sloping," so called because of the oblique appearance of the crystals which are often elongated parallel to the *b* axis) (Fig. 179), the *b* axis is the twinning axis and the twin crystals are united along a face called the rhombic section, which is parallel to *b* but slopes backward forming an angle of 27° with the edge (001) and (010). The portions of (010) above and below the line of union form an angle with each other.

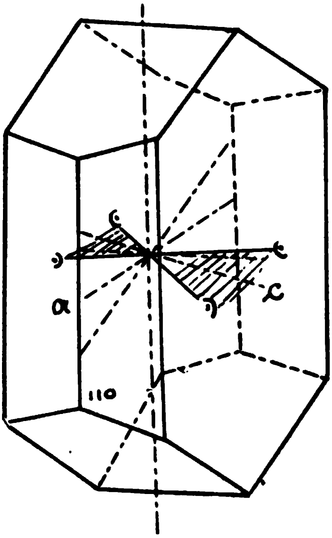


Fig. 180.—Albite, (001), (010), (110), (10̄1); axial plane.

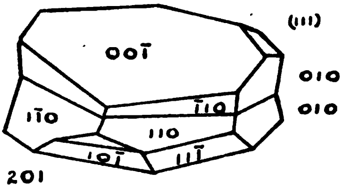


Fig. 179.—Albite, pericline twin

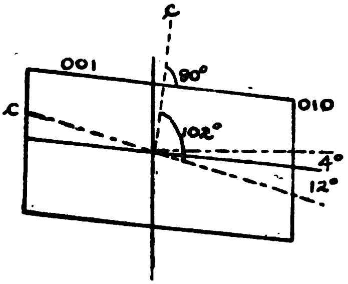


Fig. 181.—Albite section parallel (100)

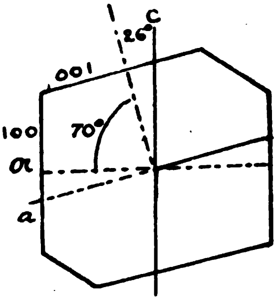


Fig. 182.—Albite section parallel (010)

Albite resembles orthoclase in hardness and fusibility but is heavier and may readily be distinguished by use of a heavy liquid like methylene iodide (sp. gr. = 3.3).

It often incloses minerals prized as gems, such as the phenacite, topaz, tourmaline, and beryl of the Urals, Ilmen, and Rocky Mountains.

SUMMARY

Albite.—$NaAlSi_3O_8$; $Na_2O = 11.8$ per cent, $Al_2O_3 = 19.5$ per cent, $SiO_2 = 68.7$ per cent. Triclinic; symmetry holosymmetric; $a:b:c = 0.6335:1:0.5577$. $\alpha = 94°3'$, $\beta = 116° 29'$, $\gamma = 88° 9'$. (110), (010), (001), $(20\bar{1})$, $(11\bar{1})$. Common twins; twinning plane and composition face (010) for albite law; axis *b* is the twinning axis and the rhombic section the composition plane for pericline law. Cleavage (001), perfect; (010), (110), imperfect; brittle; fracture uneven.

Hardness = 6; gravity = 2.63. Colorless; vitreous, transparent; $\beta = 1.533$. Double refraction positive, weak; $\gamma - \alpha = 0.011$. Acute bisectrix *c* in zone (010): (001) inclined at 16° to the perpendicular of (001). Obtuse bisectrix *a* inclined at 70° to the perpendicular of (001). Red light less dispersed than violet ($\rho < \nu$).

Insoluble; fusible at 4.

Rocky Mountains, Ural Mountains, etc.

Anorthite

The plagioclase farthest removed from albite in composition and physical character is the comparatively rare mineral anorthite ($CaAl_2Si_2O_8$) found in basalt in Japan, in limestone and augitic blocks ejected from Vesuvius, etc. The crystals are limpid glassy forms exhibiting a larger number

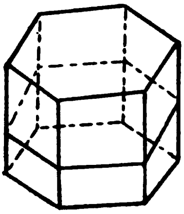


FIG. 183.—Rhombic section of anorthite.

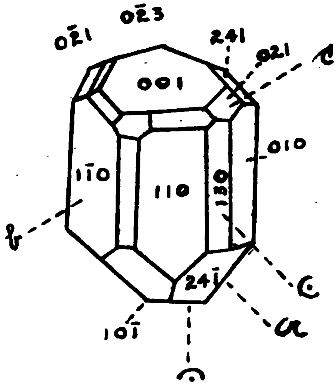


FIG. 184.—Anorthite, showing position of axial plane and bisectrix.

of faces than albite and having less marked striations on the brachypinacoid. The optical properties are very different from those of albite, as may be seen in the table (p. 144). Carlsbad, Manebach, pericline, and albite laws of twinning are exhibited. When twinned according to the pericline law the rhombic section slopes down forward from the basal plane (Fig. 183). Such a direction of slope is called negative; the backward slope such as that shown by albite is called positive.

Anorthite is heavier than albite and more difficultly fusible (5), but more easily soluble.

SUMMARY

Anorthite.—$CaAl_2Si_2O_8$; $CaO = 20.12$ per cent, $Al_2O_3 = 36.72$ per cent, $SiO_2 = 43.16$ per cent. Triclinic; symmetry holosymmetric; $a:b:c = 0.6347:1:0.5501$. $\alpha = 93° 13'$, $\beta = 115° 55'$, $\gamma = 91° 12'$. (110), (010), (001), (100), $(10\bar{1})$, $(20\bar{1})$, (021), (023), (111), $(11\bar{1})$, $(1\bar{1}1)$, (207), (130). Twinned according to Carlsbad, Baveno, Manebach, albite, and pericline laws. Cleavage (001), perfect; (010), fair. Brittle; fracture conchoidal.

Hardness = 6.5; gravity = 2.75. Colorless; vitreous; transparent; $\beta = 1.58$. Double refraction weak, negative; $\gamma - \alpha = 0.013$. Obtuse bisectrix γ perpendicular to $(02\bar{1})$. Acute bisectrix (α) inclined inside the crystal at 53° 14′ to the normal of (001), at 58° to normal of (010), at 16° 52′ to normal of $(11\bar{1})$.

Decomposed by hydrochloric acid; fusible at 5.

Vesuvius, Japan.

INTERMEDIATE PLAGIOCLASES

Oligoclase, andesine, labradorite, and bytownite are usually found as rock constituents in massive or microscopic forms lacking well-defined faces. Chemical or optical tests are necessary to distinguish these plagioclases from each other.

Oligoclase (soda lime feldspar) is found as grayish-white, translucent, somewhat greasy-looking masses with orthoclase in granite (No. 3422). The striations on the basal planes aid in distinguishing it from the orthoclase. Reddish cleavable masses with a golden shimmer due to spangles of hematite or goethite are called "adventurine feldspar" (Nos. 3423, 3424) or "sunstone."

Labradorite (lime soda feldspar), found abundantly in Labrador (Nos. 3425, 3427, 3428), the Adirondacks, and Wichita Mountains, occurs in dark cleavable masses, commonly iridescent, and showing beautiful red, yellow, and green colors. The colors are due partly to interference effects caused by twinning lamellae and partly to inclusions of hematite, goethite, or diallage. Labradorite is notably absent in rocks containing orthoclase and quartz, but is characteristic of basic rocks like gabbro and dolerite.

Often associated with the labradorite is another iridescent mineral, hypersthene. The rock formed chiefly of these two minerals is called "labrador spar" and is used extensively in decorative work. The finest church in Moscow (St. Savior), with capacity for seven thousand worshipers at one time, is wainscoted with beautiful chatoyant labradorite.

CHEMICAL CHARACTERISTICS AND SPECIFIC GRAVITY OF THE FELDSPARS

	Composition	SiO_2	Al_2O_3	K_2O	Na_2O	CaO	Specific Gravity
Orthoclase	$KAlSi_3O_8$	64.6	18.4	16.9	......	......	2.56
Microcline	....	64.6	......	......	......	......	2.56
Anorthoclase	$NaKAlSi_3O_8$	......	......	......	......	......	......
Albite	$NaAlSi_3O_8$	68.7	19.5	......	11.8	0	2.62
Oligoclase	Ab_3An	62.0	24.0	......	8.7	5.3	2.65
Andesine	AbAn	55.6	28.3	......	5.7	10.4	2.69
Labradorite	$AbAn_3$	49.3	32.6	......	2.8	15.3	2.72
Bytownite	$AbAn_6$	46.6	34.4	......	1.6	17.4	2.74
Anorthite	$CaAl_2Si_2O_8$	43.2	36.7	......	0.	20.1	2.75

CRYSTALLOGRAPHIC CHARACTERISTICS OF THE FELDSPARS

	Axes	Angle between Axes			Extinction on 001	Extinction on 010	Mean Refraction β	Rhombic Section Angle
	a: b: c	α	β	γ				
Orthoclase	0.658:1:0.555	90°	116°3′	90°	0°0′	5°	1.523	.....
Microcline	0.658:1:0.555	89°30′	116°3′	90°	15°30′	5°	1.526	.....
Anorthoclase	....	......	......	......	......	......	......	.....
Albite	0.633:1:0.557	94°3′	116°29′	88°9′	4°30′	19°	1.534	27°
Oligoclase	0.632:1:0.552	93°4′	116°23′	90°5′	1°4′	4°36′	1.542	3°
Andesine	0.635:1:0.552	93°23′	116°29′	89°59′	5°10′	16°	1.558	1°
Labradorite	0.637:1:0.554	93°31′	116°3′	89°54′	17°40′	29°28′	1.570	9°
Bytownite	....	......	......	......	27°33′	33°29′	......	10°
Anorthite	0.634:1:0.550	93°15′	115°55′	91°12′	37°	36°	1.582	16°

Leucite

Leucite (λευκός, "white") crystallizes in white, round crystals (Fig. 7) from an inch in diameter to forms microscopic in size in igneous rocks, such as those found in the Leucite Hills, southwestern Wyoming, and at Mount Vesuvius (No. 3244).

When leucite assumes its definite form at temperatures above 500° the crystals are trapezohedrons, but at ordinary temperatures, while the external form remains the same, the internal condition is that of the orthorhombic system. The microscope reveals multitudes of fine layers which cross each other at right angles, and occasionally groups diagonal to these (Fig. 185). These layers have the optical properties characteristic of the orthorhombic system. Hence leucite is said to be pseudo-regular. Externally it is always regular, internally under ordinary conditions it is orthorhombic. Crystals microscopic in size are often free from the orthorhombic layers. Furthermore, inclusions of other minerals, such as augite, olivene, and apatite, are arranged parallel to trapezohedral faces—an additional indication that the mineral swings between the orthorhombic and the regular system. Its instability is further shown by the fact that in nature it is usually white and opaque, owing to its change into analcite, mica, or kaolin.

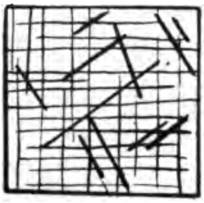


FIG. 185.—Microscopic section of leucite between crossed nicols.

SUMMARY

Leucite.—$KAl(SiO_3)_2$; $K_2O = 21.58$ per cent, $Al_2O_3 = 23.40$ per cent, $SiO_2 = 55.02$ per cent. Orthorhombic (211). At ordinary temperature all but microscopic crystals contain fine orthorhombic lamellae which are weakly doubly refracting. Cleavage parallel (110) imperfect; brittle; fracture conchoidal.

Hardness = 5.5; gravity = 2.5. Colorless; vitreous; transparent; $\beta = 1.508$.

Infusible; soluble in hydrochloric acid.

Vesuvius, Eifel, Wyoming.

PYROXENE GROUP

Hardly less abundant than the white feldspars as rock constituents are the colored pyroxenes. The name pyroxene (πῦρ, ξένος, "a stranger to fire") was given by Haüy to certain green crystals found in Italian lavas, with the thought that they were only accidentally present, having been caught up while the lava was passing surrounding rock. Now it is known that they are essential constituents of many igneous rocks and are as much misnamed as is a white blackbird! According to their crystallography, they are classified in three sections, the orthorhombic, the monoclinic, and the triclinic. Most prominent in the first section are

ORTHORHOMBIC PYROXENES

Enstatite and Hypersthene

Enstatite is a white, green, or brownish mineral occurring rarely in columnar, orthorhombic crystals, and commonly in fibrous, silky, opaque masses. Measurable crystals were found by von Lang in 1871 in a meteorite which fell in Bohemia, and three years later certain large crystals contained in Norwegian schists were found to be enstatite by Brögger. Chemically enstatite is a magnesium silicate ($MgSiO_3$). The presence of iron often gives a metallic luster (bronzite). When iron replaces a large part of the magnesium, a somewhat darker, heavier, and more soluble mineral, hypersthene, results.

When a thin section of either of these minerals cut parallel to the prism or brachypinacoid plane is viewed under a microscope between crossed nicols, it becomes dark if the crystal axes are parallel to the cross-hairs of the microscope, as is characteristic of an orthorhombic mineral. The extinction is said to be parallel. Further, these pyroxenes change from reddish-brown to green according to the direction in which a thin section is viewed under the microscope. That is, they are strongly pleochroic, and this property aids in distinguishing them from the pyroxenes next to be studied.

Both enstatite and hypersthene are found in granular eruptive rocks and schists such as are common in most mountain regions.

SUMMARY

Enstatite.—$MgSiO_3$; $MgO=40$ per cent, $SiO_2=60$ per cent. Orthorhombic; $a:b:c=0.97:1:0.57$. $(110):(1\bar{1}0)=88° 20'$. Cleavage parallel (110), (010). Brittle; fracture even.

Hardness = 5.5; gravity = 3.2. White, green, brown; vitreous; translucent; mean refraction $\beta=1.659$. Double refraction weak, positive; $\gamma-\alpha=0.009$. Axial plane (010); acute bisectrix, normal to (001), $2H=79°$; $\rho<v$.

Infusible, named after ἐνστάτης, "opponent," because so refractory. Insoluble; with cobalt turns pink. Decomposes into serpentine and talc.

New York, Norway, Germany. Common in meteorites.

Hypersthene.—$(MgFe)SiO_3$; MgO from 26 to 11 per cent, FeO from 10 to 34 per cent. Agrees with enstatite except as follows:

Gravity$=3.4$. Dark green to black. $\beta=1.702$. Double refraction weak, negative; $\gamma-\alpha=0.013$. Acute bisectrix normal to (100). Dispersion $\rho>\nu$.

Fusible to magnetic mass. Partly soluble in hydrochloric acid.

Common with labradorite in granular eruptive rocks in Labrador, Greenland, Norway, New York.

MONOCLINIC PYROXENES

The monoclinic section of pyroxenes is more important than either the orthorhombic, already considered, or the triclinic, which will be studied later. The chief monoclinic pyroxenes are

Diopside and Augite

These two minerals occur in short, stout, green to black crystals in igneous rocks, and are nearly as abundant as is the feldspar in these rocks (Nos. 3676, 3677, 3680).

Diopside (Nos. 3429 and 3430) is clear pale green in color. Sometimes a crystal is darker at one

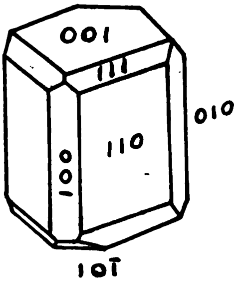


Fig. 186*a*.—Diopside

Fig. 186*b*.—Photograph of diopside from Cantley, Quebec, Canada: (111), (100), ($\bar{1}$01), (110), (100), (010); about 12 inches long.

end than at the other, and also differently terminated at the opposite ends. The usual shape of the crystal is illustrated in Figures 186–88. In composition diopside is a silicate of calcium and magnesium, $CaMg(SiO_3)_2$.

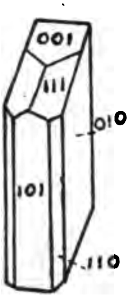


Fig. 187.—Diopside

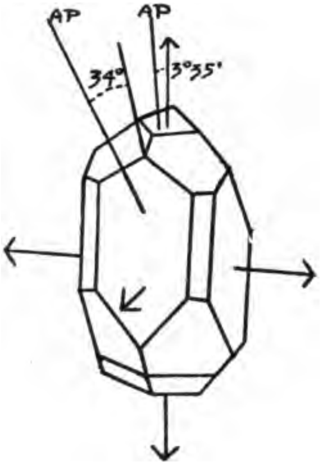


Fig. 188.—Diopside, showing optic axes, acute bisectrix, axes of elasticity.

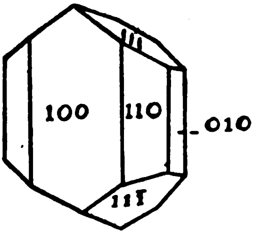


Fig. 189.—Augite

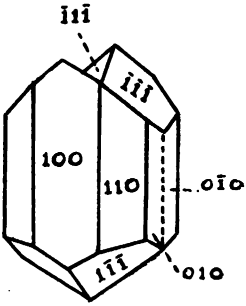


Fig. 190.—Augite twin parallel to (100)

Augite is dark green or black (No. 3431). The crystals are usually terminated with pyramidal planes, while prism and pinacoid planes are both well developed. Twins parallel to the orthopinacoid are common (Figs. 189 and 190).

While iron is usually present in both diopside and augite, it is more abundant in the latter. Diopside lacks aluminum. Therefore the pyroxenes are often divided into non-aluminous (diopside) and aluminous (augite) varieties.

Light green or white diopside is abundant in crystalline limestones and dolomites. Green or black augite is common in granite or eruptive rocks (No. 3433). When black basalt decomposes, augite crystals sometimes fall out and may be easily collected in quantities.

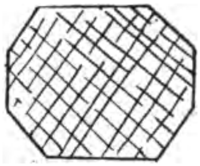


FIG. 191.—Augite cross-section perpendicular to prism planes.

A thin section of augite cut perpendicular to the *c* axis when viewed under the microscope shows fine cleavage lines parallel to the prism planes. These lines form an angle of nearly 90° with each other and the outline of the figure is eight-sided (Fig. 191). The eight-sided outline, the cleavage angle, and lack of pleochroism aid in distinguishing augite from hornblende. Hornblende presents a six-sided figure with cleavage line forming an angle of 124°, and furthermore is strongly pleochroic.

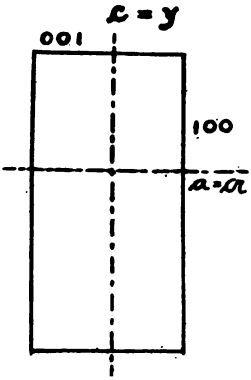


FIG. 192.—Enstatite, showing parallel extinction.

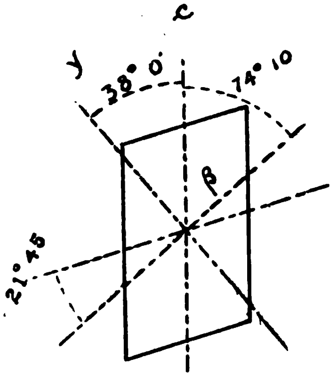


FIG. 193.—Diopside, showing oblique extinction angle of 38°.

Fragments or thin sections of the members of the pyroxene group may be recognized by their extinction angle. A section of enstatite cut parallel to the brachypinacoid and viewed in parallel light between crossed nicols becomes dark when the *c* axis is parallel to one of the cross-hairs of the microscope (Fig. 192). Diopside when so examined must be turned clockwise about 38° before it becomes dark (Fig. 193). Augite requires even a greater angle of revolution, sometimes being as large as 54°. In each case the angle of extinction increases with the amount of iron present.

SUMMARY

Diopside.—$CaMg(SiO_3)_2$; $CaO=25.9$ per cent, $MgO=18.5$ per cent, $SiO_2=55.6$ per cent. Monoclinic; $a:b:c=1.0921:1:0.5893$. $\beta=105° 50'$. (110), (100), (010), (001), $(10\bar{1})$, $(\bar{1}11)$, $(\bar{2}21)$. Twinned on (100). Cleavage perfect parallel (110), imperfect parallel (100), (010). Brittle; fracture conchoidal.

Hardness = 5.5; gravity = 3.3. Light green; vitreous; transparent. Mean refraction $(\beta)=1.681$, maximum $(\gamma)=1.703$. Double refraction positive, strong; $\gamma-\alpha=0.030$. Axial plane (010). Acute bisectrix inclined 37° 35′ to *c* and the obtuse bisectrix inclined below *a* in front 21° 45′ (Fig. 193). Axial angle $(2\,E)=68°$.

Fusible; insoluble.

In crystalline limestones and dolomites, both east and west, and in the drift.

Augite.—$\left\{\begin{matrix}CaMg(SiO_3)_2\\ MgAl_2SiO_6\end{matrix}\right\}$ Fe_2O_3 is also always present.

Augite has nearly the same character as diopside, but contains Al_2O_3 and Fe_2O_3 in addition to calcium and magnesium silicates, and is darker in color.

More readily fusible than diopside.

In granitic and eruptive rocks the world over.

Jadeite

Jadeite is a compact, tough, alkaline pyroxene having the composition $NaAl(SiO_3)_2$. It is 7 in hardness and 3.3 in specific gravity, is translucent, and varies in color from blue and green to white. When carved and polished it has a soft waxy luster which is very pleasing, and for that reason it has been used for many hundreds of years as material for carving into ornaments, vases, etc. Being tough and hard, it is very enduring.

SUMMARY

Jadeite.—$NaAl(SiO_3)_2$; $Na_2O = 15.4$ per cent, $Al_2O_3 = 25.2$ per cent, $SiO_2 = 59.4$ per cent. Monoclinic; massive, sometimes granular, slightly fibrous; fracture splintery; very tough.

Hardness = 7; gravity = 3.3. Greenish, bluish, white; waxy, dull, translucent; $2\ V = 72°$.

Fuses readily; not attacked by acids after fusion; different from saussurite.

Burma, Thibet, Mexico.

TRICLINIC PYROXENE

The triclinic pyroxene rhodonite (ῥόδον, "a rose") is a beautiful red mineral which, because of its hardness (6) and fine color, is used for ornaments such as brooches, cuff buttons, watch charms, inkwells, paper weights, vases, mantelpieces, and table tops. In the Urals masses of such size have been found as to be available for tombstones. In the late Czar's lapidary shops at Petrograd some years ago, the author saw an oblong block of rhodonite 7×4×3 feet in size, being carved for a sarcophagus for royalty, and which was valued at six hundred thousand dollars.

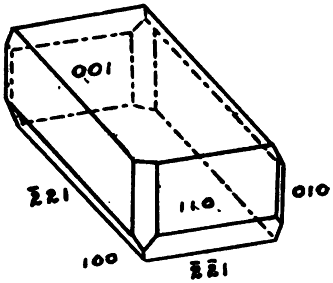


FIG. 194.—Rhodonite

When crystals of rhodonite occur, as is often the case in Norway, England, and New Jersey (No. 3438), they are tabular (Fig. 194) in form or stout like augite.

Rhodonite is a silicate of manganese ($MnSiO_3$) but usually contains calcium, iron, and in New Jersey zinc.

SUMMARY

Rhodonite.—$MnSiO_3$; $MnO = 54.1$ per cent, $SiO_2 = 45.9$ per cent. Triclinic; $a:b:c = 1.073:1:0.621$. $\alpha = 103° \ 18'$, $\beta = 108° \ 44'$, $\gamma = 87° \ 39'$. (110), (010), (001), $(22\bar{1})$. Cleavage $(1\bar{1}0)$, (110), perfect; (001), fair. Brittle; fracture uneven.

Hardness = 6; gravity = 3.6. Red; vitreous; translucent. Mean refraction $(\beta) = 1.73$. Double refraction negative, weak; $\gamma - \alpha = 0.010$. Axial plane is inclined at 63° to $(1\bar{1}0)$ and 38° to (001). Acute bisectrix inclined 51° 47′ to the normal of $(1\bar{1}0)$ and 51° 40′ to the normal of (001). Axial angle $(2\,H) = 79°$; $\rho < \nu$.

Readily fusible (2.5); partly soluble in hydrochloric acid.

Urals, Norway, England, New Jersey.

AMPHIBOLE GROUP

The minerals in this group resemble pyroxene in composition, color, and form.

Like the pyroxenes they have orthorhombic, monoclinic, and triclinic representatives. The term amphibole (αμφιβολη, "doubtful") was given by Haüy to replace the name "schorl" used by miners for both hornblendes and tourmaline—two minerals which, though resembling each other, are chemically and crystallographically different. The readiest means of distinguishing amphiboles from pyroxenes are the crystal form and cleavage, as may be seen from the descriptions following.

ORTHORHOMBIC AMPHIBOLE

Anthophyllite, corresponding to the orthorhombic pyroxene, hypersthene, occurs in brown fibrous or flaky masses in mica schist in Norway, Pennsylvania (No. 3440), North Carolina, etc. Crystals are extremely rare, but under the microscope it may be observed that cleavage parallel to (010) is inferior to that of hypersthene. Anthophyllite is less pleochroitic than hypersthene but has greater double refraction; $\gamma - \alpha = 0.024$.

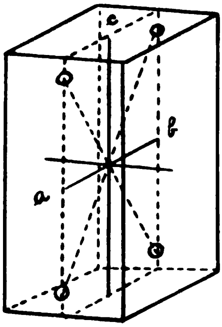


FIG. 195.—Anthophyllite, axial plane and optic axes.

The name anthophyllite is derived from the Latin word for clove (*anthophyllum*) because of the clove-brown color of the mineral.

SUMMARY

Anthophyllite.—(MgFe)SiO_3; MgO = 27.8 per cent, FeO = 16.6 per cent, SiO_2 = 55.6 per cent. Orthorhombic; crystals rare; fine fibers or flakes common.

Hardness = 6; gravity = 3.1. Brown to green, at times metalloidal; translucent. Mean refraction $(\beta) = 1.642$. Double refraction positive;

$\gamma - \alpha = 0.024$. Axial plane parallel (010). Acute bisectrix normal to (001).

Difficultly fusible; insoluble.

In gneisses and schists in Norway, Pennsylvania, North Carolina, etc.

MONOCLINC AMPHIBOLES

As the monoclinic pyroxenes are the most abundant and important of the pyroxenes, so the monoclinic amphiboles far surpass in abundance the orthorhombic and triclinic forms. The white tremolite, green actinolite, and black hornblende constitute the chief representatives of the monoclinic forms.

Tremolite

Tremolite corresponds to diopside but contains more magnesium and is usually fibrous or columnar and without terminating planes. It is white or pale green in color. As the amount of iron (FeO) increases, it becomes dark and is called actinolite (Nos. 3474, 3475), from the fact that it occurs in blades or rays (ἀκτῖνος, "ray").

Tremolite is found in granular dolomite and actinolite in schists in the Alps and Appalachians (Nos. 582, 3435, 3444, and 3446) and other mountainous regions.

Actinolite is strongly pleochroic. Light passing through parallel to *a* is greenish yellow, parallel to *b* yellowish green, and parallel to *c* green.

SUMMARY

Tremolite.—$CaMg_3(SiO_3)_4$; $CaO = 13.45$ per cent, $MgO = 28.83$ per cent, $SiO_2 = 57.72$ per cent. Monoclinic; $a:b:c = 0.551:1:0.294$. $\beta = 106°2'$. (110), (100), (010). Twinning plane 100. Cleavage (110) perfect; (100), (010) imperfect. Brittle; fracture uneven.

Hardness = 5.5; gravity = 3.1. Pale green; vitreous; translucent. Mean refraction $(\beta) = 1.62$; maximum $(\gamma) = 1.63$. Double refraction negative, strong; $\gamma - \alpha = 0.028$. Axial plane (010); acute bisectrix almost parallel to (001). Axial angle $(2N) = 87° 22'$; $\rho < \nu$. Extinction angle (between γ and c) $= 15°$.

Fusible; insoluble.

Crystalline dolomites and schists in many mountain regions.

Hornblende

Hornblende is the common black amphibole corresponding to augite, the common black pyroxene. It may be distinguished from augite since the crystals and also their transverse sections are usually six-sided rather than eight-sided (Figs. 196–99) and the cleavage lines parallel to prism planes make an angle of 56°. In hardness, weight, etc., the two minerals are similar.

The chemical composition of hornblende is not as well understood as that of augite, but it may probably be best represented as a mixture of the actinolite molecule $Ca(Mg,Fe)_3(SiO_3)_4$ and a molecule containing aluminum in addition to the calcium and magnesium, thus $CaMg_2Al_2(SiO_4)_3$.

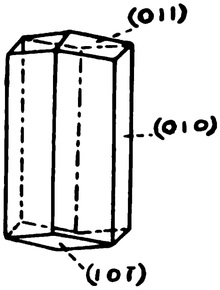


Fig. 196.—Hornblende

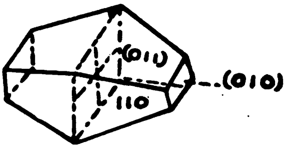


Fig. 197.—Hornblende

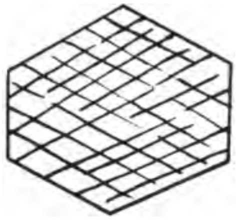


Fig. 198.—Horneblende section perpendicular to prism.

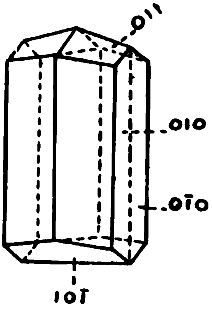


Fig. 199.—Hornblende twinned on (100).

Hornblende is found in lava, as at Vesuvius, and in basalt, trachyte, gneiss, and schists in most mountain regions (Nos. 3441, 3442, 3443).

Excellent crystals weathering out of volcanic rocks show abundant twins parallel to the orthopinacoid (100) (Fig. 199).

SUMMARY

Hornblende.—$\left\{\begin{matrix}Ca(MgFe)_3(SiO_3)_4\\CaMg_2Al_2(SiO_4)_3\end{matrix}\right\}$. Crystallography the same as that of tremolite, but end planes are common; (001), (011), (10$\bar{1}$), (130). Cleavage parallel (110) with angle of 56° perfect. Brittle to tough.

Hardness = 5.5; gravity = 3.2. Dark green to black; vitreous; translucent to opaque. Color and optical properties vary with the amount of iron present. Mean refraction (β) = 1.64 to 1.72. Double refraction positive, strong; $\gamma - \alpha = 0.019$ to 0.072. Axial plane (010). Axial angle (2*H*) = 59°. Extinction angle (between γ and *c*) = 15°. Strong interference; strong pleochroism, *c* greenish blue, *b* emerald green, *a* greenish yellow.

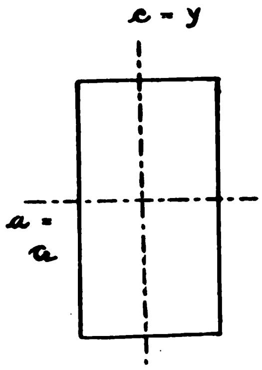


FIG. 200.—Anthophyllite; parallel extinction.

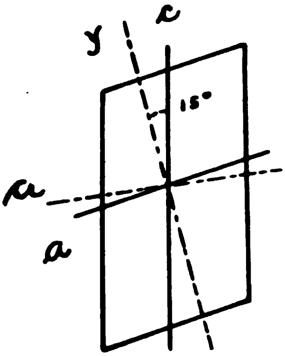


FIG. 201.—Tremolite; extinction angle 15°.

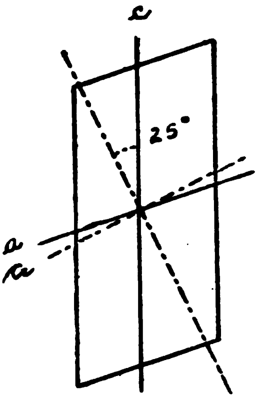


FIG. 202.—Hornblende; extinction angle 25°.

Fuses readily and may become magnetic; insoluble.

Mountain ranges, in volcanic and metamorphic rocks.

Asbestos

Asbestos is a kind of amphibole with fibers (Nos. 479, 480) which are of sufficient length and flexibility to permit of its being woven into cloth. In northern Italy (Lombardy) is found a white asbestos whose silky fibers are often three feet long. Usually the fibers are but an inch or less in length. When too short for weaving, they are used for insulation, fireproof packing, etc., since the mineral is a poor conductor of heat and is infusible. The greater part of the asbestos used commercially is a fibrous variety of serpentine, a mineral to be described later.

"Mountain cork" and "mountain leather" are matted sheets or nodules of yellowish asbestos.

Georgia produces amphibole asbestos. Arizona, California, and Wyoming yield serpentine asbestos. But our chief supply is the chrysotile (fibrous serpentine) imported from Canada. It is woven into cloth (No. 1876) for theater curtains, gloves, firemen's suits, etc.; made into yarn, rope, paper, and boards; and used for covering steam pipes, lining safes, making paints, filters, etc.

In Griqualand, Africa, is found a fibrous, silky, blue chatoyant amphibole known as crocidolite (Nos. 3476 and 3478). Through oxidation and partial replacement by silica, this becomes converted into a hard, compact, golden-yellow mineral known as "cat's eye" or "tiger eye," and much used for ornaments.

Nephrite

Nephrite (jade) is another variety of amphibole. It is compact, has a specific gravity of 3, and is harder than other amphiboles, its hardness being 6.5. It is one of the toughest of minerals, and has a splintery fracture. The white variety has the composition of tremolite, and the green variety that of actinolite. On account of its toughness, color, and translucency, like jadeite it has been much prized for centuries throughout the East as a material from which to carve ornaments and weapons. The ancients thought it a cure for kidney diseases (*νεφρός*, "kidney"; jade has the same meaning). It is found as bowlders in China, India, New Zealand, Alaska, Mexico, and Germany.

Beryl

When beryllium aluminium silicate ($Be_3Al_2Si_6O_{18}$) occurs in greenish masses or in coarse, hexagonal, prismatic crystals, it is called beryl. Transparent, beautiful pale-green crystals are called aquamarine. The dark-green crystals are called emerald, and are among the most prized of gem minerals. Aquamarine means sea water; emerald and beryl are ancient names of unknown signification (Fig. 203*a*).

Beryl furnishes the best example of holosymmetric hexagonal symmetry found among minerals. Little, bright, pale-green crystals with many faces occur in Siberia and in the Urals (Fig. 203*b*).

Ekaterinburg, Russia, has long been known as a good source for aquamarines and emeralds. They are found in a coarse granite associated with topaz, black tourmaline, and smoky quartz in the neighboring mountains.

A tourmaline granite on the island of Elba and an albitic granite in the Mourne Mountains, Ireland, contain richly terminated beryls which vary in tint from colorless to green, blue, or red.

FIG. 203*a*.—Photograph of beryl from Brazil, (0001) and (10$\bar{1}$0).

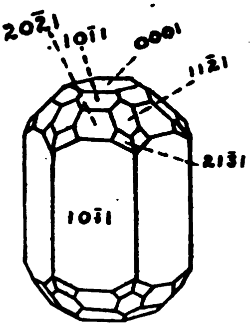


FIG. 203*b*.—Beryl

The best emeralds have been procured from Muso, Colombia, in a black, bituminous limestone, where they are accompanied by pyrite, calcite, black dolomite, and quartz. The prism form is strongly developed. The crystals have often been fractured and recemented by calcite.

Coarse beryl of gigantic dimensions has been found in New Hampshire and Massachusetts. Nos. 1667, 3232, and 500 represent the New Hampshire locality. No. 3483 comes from Connecticut. Colorado (No. 3482) and North Carolina have furnished quantities of beryl and a few emeralds.

Beryl crystals are often striated vertically and are usually without termination. They cleave imperfectly parallel to the base. Although without doubt hexagonal, they often show weak double refraction because of strain. They resemble apatite but may be distinguished by their inferior cleavage and superior hardness.

Chromium doubtless furnishes the color to emerald and aquamarine. Flawless crystals are extremely rare.

SUMMARY

Beryl.—$Be_3Al_2Si_6O_{18}$; $BeO = 14.11$ per cent, $Al_2O_3 = 19.05$ per cent, $SiO_2 = 66.84$ per cent. Hexagonal; holosymmetric; $a:c = 1:0.4989$. $(10\bar{1}0)$, $(10\bar{1}1)$, $(20\bar{2}1)$, $(11\bar{2}1)$, (2131), (0001). Cleavage parallel (0001) imperfect. Brittle; fracture conchoidal.

Hardness = 7.5; gravity = 2.7. Bluish green; vitreous; transparent. $\omega = 1.584$; double refraction negative, weak; $\omega - \epsilon = 0.006$.

Fusible with difficulty (5.5). Insoluble.

Urals, Maine, New Hampshire, North Carolina, South Dakota, Colorado.

GARNET GROUP

Each of the six varieties of garnet which compose this group crystallizes in remarkably well-formed dodecahedrons, trapezohedrons, or combinations of these forms (Figs. 204–6). All have imperfect cleavage, conchoidal fracture, high refraction, and greasy luster. In color they are usually red, brown, or black, though some varieties are green or yellow.

They are silicate of calcium, magnesium, manganese, iron, aluminium, and chromium in isomorphous mixtures. Because they are mixtures their color, weight, fusibility, and solubility are variable, as may be seen in the following table:

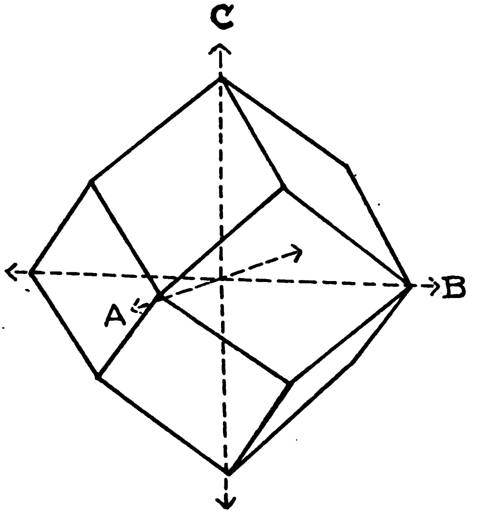
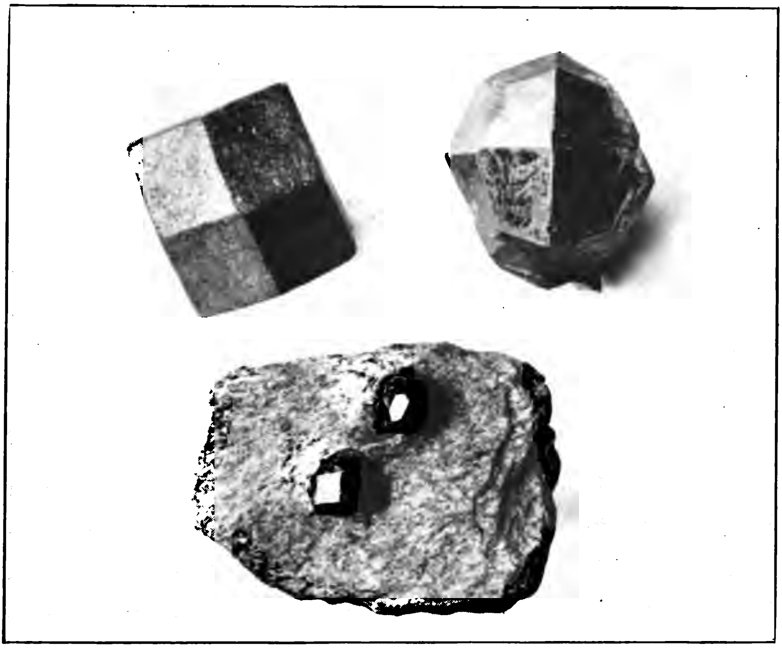


Fig. 204.—Garnet

PLATE XXVII



a, Garnets; dodecahedron from Salida, Colorado, trapezohedron from North Carolina, and combination from Fort Wrangel, Alaska.

b, A dodecahedron nearly four inches in diameter from Salida, Colorado.

Grossularite, $Ca_3Al_2(SiO_4)_3$; gravity, 3.5; hardness, 7; fusible (3); yellowish to red or brown.

Pyrope, $Mg_3Al_2(SiO_4)_3$; gravity, 3.7; hardness, 7; fusible (3.5); deep red to black.

Almandite, $Fe_3Al_2(SiO_4)_3$; gravity, 3.5–4.3; hardness, 7; fusible (3); deep red to black.

Spessarite, $Mn_3Al_2(SiO_4)_3$; gravity, 3.8; hardness, 7; fusible (3); purple red to brown.

Uvarovite, $Ca_3Cr_2(SiO_4)_3$; gravity, 3.4; hardness, 7; infusible (6); green.

Andradite, $Ca_3Fe_2(SiO_4)_3$; gravity, 3.8–4.1; hardness, 7; fusible (3); yellow, red, black.

The ordinary varieties of garnet are abundant enough to be mined for use as an abrasive in New York, New Hampshire (No. 616), North Carolina, and Georgia. The only garnets found in Illinois are those occurring in gneiss and schists transported from the north by glaciers. Dentists use garnet disks for polishing, as do also shoe manufacturers, woodworkers, etc. At Morelos, Mexico, a marble containing large pink garnets is polished for ornamental slabs.

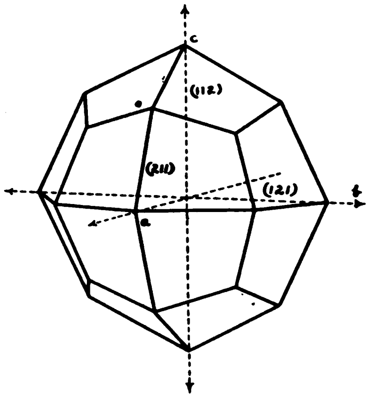


FIG. 205.—Garnet

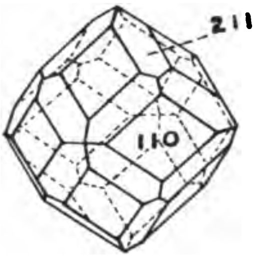


FIG. 206.—Garnet

Pyrope (πυρωπός, "fiery eyed") (Nos. 3489 and 3177) and almandite are much used in common jewelry, the former often being of a fine, transparent red color resembling ruby, and the latter of a purplish or hyacinth-red color. Almandite is often cut *en cabochon*, i.e., with flat base and rounded top.

Uvarovite (named after a Russian minister), found in small, brilliant green crystals in a serpentine rock in the Urals and in granular limestones in Canada, is cut into gem stones and sold as "olivine," though the latter mineral is no harder nor superior in any respect to uvarovite.

Under the microscope garnet crystals show square or hexagonal outlines and an absence of cleavage. They are isotropic and so strongly refracting (n=from 1.7 to 1.8) as to present a bold relief and shagreenous surface.

Garnet occurs most commonly as crystals, from the size of a pea to that of a boy's marble, in crystalline schists, gneisses, and granulite, and as grains in phonolite and leucitophyre. Sometimes large masses associated with hornblende and magnetite constitute a garnet rock. Garnet, green augite, and hornblende form eclogite, which is by some regarded as the parent rock of diamonds.

Grossularite (Nos. 3486, 3488, 3490), the lime aluminium garnet, is typically found in metamorphic rocks, such as marbles; pyrope, the magnesium aluminium garnet, in basic rocks containing magnesium; almandite, the iron aluminium garnet, and spessartite, the manganese aluminium garnet, in granitic and gneissic rocks; while andradite, the lime iron garnet, is of widespread occurrence.

The Urals, Alps, Pyrenees, Appalachians, and Cordilleras have all furnished multitudes of various kinds of garnets.

SUMMARY

Garnet.—$(Ca,Mg,Fe,Mn)_3(Al,Fe,Cr,)_2(SiO_4)_3$. Regular; 110, 211. Cleavage (110) imperfect; brittle; fracture uneven.

Hardness=7 to 7.5; gravity=3.8. Honey-yellow to black; luster vitreous; transparent; ω=1.7–1.8.

All except uvarovite soluble with difficulty; andradite most readily. Iron garnets fuse to magnetic globules.

Mountain regions generally.

Zircon

Zircon, a brown zirconium silicate, nearly always occurs in crystals, since it is one of the first minerals to solidify out of the molten magma which forms augite syenite, elaeolite syenite, and other igneous rocks. In crystalline schists and gneiss the crystals are usually microscopic in size, but may be readily identified by their square outlines, brown color, and by their high refraction (1.930) and double refraction (0.062), which give them a bold relief and in an ordinary rock section interference colors of the third order. Because of its hardness and insolubility zircon resists decomposition, and is found with gold, platinum, cassiterite, and magnetite in the heavy sands which result from the destruction of granites and gneisses.

Figures 207 and 208 represent the common forms of the simple crystal. By enlargement of the pyramid (311) acute termination results. With zircon, as with cassiterite and quartz, basal planes are rarely developed.

Clear varieties (No. 3494) are much prized as gems because of their hardness (7.5), high refraction, and great dispersion.

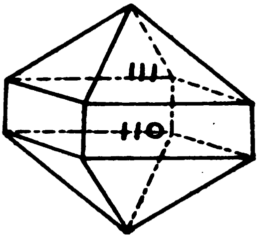


FIG. 207.—Zircon

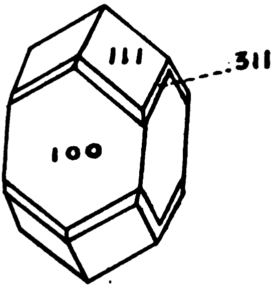


FIG. 208.—Zircon

In refraction and dispersion they come next to diamonds. In color they vary from colorless through various shades of orange, yellow, red ("jacynth"), pale green, and gray ("jargoon"). When dark brown they become opaque. The color is due to Fe_2O_3 and can be altered by heating in the blowpipe flame.

When finely powdered, zircon is slowly decomposed in hot sulphuric acid.

Ceylon, the Urals, Alps, Norway, North Carolina, Arkansas, and Colorado have all furnished fine specimens of zircon.

SUMMARY

Zircon.—$ZrSiO_4$; $ZrO_2=67.2$ per cent; $SiO_2=32.8$ per cent. Tetragonal; holosymmetric. $a:c=1:0.64$. (111), (311), (100), (110). Cleavage parallel (111), (110), imperfect. Brittle; fracture conchoidal.

Hardness = 7.5; gravity = 4.7. Brown; luster adamantine; subtranslucent; $\omega = 1.93$. Double refraction positive, strong; $\epsilon - \omega = 0.062$.

Infusible; insoluble.

Ceylon, Urals, Norway, North Carolina, Colorado.

Topaz

The name topaz is given to a mineral which is hard, colorless, transparent, prismatic, often vertically striated, usually terminated at one end by several pyramid planes and a basal plane, easily cleavable parallel to the base, and in chemical composition is a silicate of aluminium and fluorine $Al_2(FOH)_2SiO_4$.

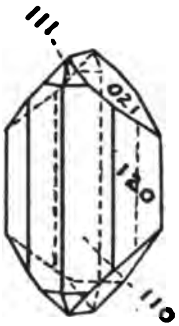


FIG. 209.—Topaz

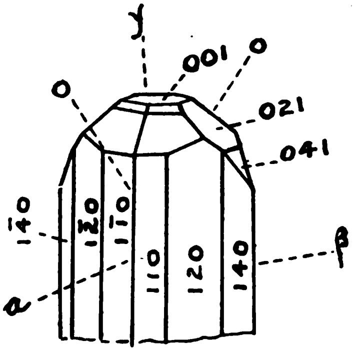


FIG. 210.—Topaz, showing optic axes (o) and axial plane.

Many crystals are delicately or deeply colored. Pale-blue crystals are found with orthoclase, smoky quartz, and beryl in granite at Nerchinsk, Siberia (No. 1890); and dark-blue crystals at Mursinsk in the Urals in a similar rock accompanied by lepidolite. Deep brown crystals are found on the Urulga River in the Urals, and in Minas Geraes, Brazil (No. 3493). The brown crystals when heated often become pink. Some regions furnish golden-yellow crystals, but the great majority of occurrences are white or colorless. Many limpid, richly planed crystals are found in Utah and Colorado.

Like cassiterite, topaz was formed under the influence of heat and in the presence of vapors containing fluorine.

Attractive color, together with high refraction and great hardness, places topaz among the gems.

SUMMARY

Topaz.—$Al_2(FOH)_2SiO_4$; $Al_2O_3 = 55.44$ per cent, $F = 20.65$ per cent, $SiO_2 = 32.61$ per cent. Orthorhombic; $a:b:c = 0.528:1:0.477$. (001), (111), (110), (120), (221), (223), (201), (021), (041), (140). Cleavage parallel (001) perfect. Brittle; fracture sub-conchoidal.

Hardness = 8; gravity = 3.5. Pale yellow; vitreous; transparent. $\beta = 1.618$; $\gamma = 1.623$. Double refraction positive, weak; $\gamma - \alpha = 0.011$. Axial plane (010). Acute bisectrix normal to (001); $2E = 114°$. Dispersion strong; $\rho > \nu$.

Infusible; difficultly soluble.

Urals, Brazil, Japan, Utah, Colorado, California, Missouri.

Cyanite

This mineral (No. 3496), which easily attracts attention because of its blue color (κυανός, "blue"), occurs in long, flat, bladed crystals that show a remarkable difference in hardness in different directions. Across the blades, that is, parallel to the edge made by the macropinacoid (100) and base (001), the hardness is 7, while along the crystal, that is, parallel to the edge formed by the macropinacoid (100) and brachypinacoid (010), the hardness is only 4.5. When Haüy discovered this property, he named the mineral disthene (δίς and σθένος, "double strength"). When cyanite is heated at 1350° C. without changing its chemical composition (Al_2SiO_5) it is transformed into a fibrous mineral of uniform hardness (6.5), lighter specific gravity (3.2; cyanite is 3.6), and straight extinction. The mineral is called sillimanite, and is characteristic of some gneisses and schists. Compact sillimanite (sometimes wrongly called jade) was used in prehistoric times in the manufacture of ornaments and implements.

SUMMARY

Cyanite.—Al_2SiO_5; $Al_2O_3 = 63$ per cent, $SiO_2 = 37$ per cent. Triclinic; $a:b:c = 0.899:1:0.697$. (001), (100), (010), (110). Cleavage parallel (100) perfect; (010) imperfect. Brittle; fracture fibrous.

Hardness = 7 across the crystal, 4.5 parallel to the edge (100); (010); gravity = 3.6. Blue to white; vitreous; transparent. $\beta = 1.72$. Double refraction negative; $\gamma - \alpha = 0.016$. Axial plane inclined 30° to edge (100); (010). Acute bisectrix normal to 100: $2H = 100°$.

Infusible; insoluble.

Alps, northern England, Appalachians, Cordilleras.

Tourmaline

This mineral is worthy of notice for three reasons: first, because it is abundant in igneous and metamorphic rocks; second, because it is used in making optical instruments such as "tourmaline tongs" (see below, p. 166); and third, because the beautiful red, pink, and green varieties are used as gems (Plate XXVIII). Tourmaline is literally found "from Maine to California." Paris, Maine (Nos. 444, 454, 4062), has long been reputed for its magnificent red and green crystals, and more recently San Diego County, California (Nos. 3511, 3788, 3789, 3790), has furnished the museums of the world with handsome groups of red tourmaline (rubellite) in a lavendar mica, lepidolite. The tourmalines of Illinois are all emigrants from northern regions. Black is the prevailing color, and they are usually imbedded in gneisses and granites. Among the most famous foreign localities may be mentioned the region near Ekaterinburg in the Urals, where a coarse granite contains smoky quartz, albite, green and pink mica, and red and fine black tourmaline. At Campologna, Switzerland, calcite, corundum, diaspore, mica, and green tourmaline are found in a granular dolomite. The granite of the island of Elba consists of quartz, orthoclase, albite, mica, pink beryl, red garnet, and red and black tourmaline. The best gem tourmalines are obtained in Ceylon.

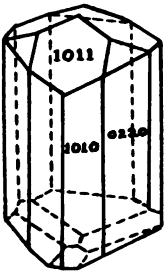


FIG. 211.—Tourmaline

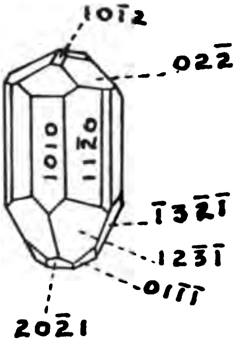


FIG. 212.—Tourmaline

Tourmaline crystals (Nos. 357 and 3505) (Figs. 211 and 212) are usually prismatic, often elongated, sometimes terminated at one end,

PLATE XXVIII

a, Tourmaline doubly terminated; variously colored crystal from Mesa Grande, California.

b, Black, well-crystallized specimen from Haddam, Connecticut.

rarely at both ends. Occasionally they are flat crystals. Prisms are strongly striated vertically. This striation, the triangular cross-sections, and absence of cleavage serve to distinguish this mineral from black pyroxenes and amphiboles.

The chemical constitution of tourmaline is complex and is still the subject of much discussion. Generally speaking, it is a borosilicate of aluminum, iron, or chromium, of magnesium, and of the alkalies sodium, potassium, and lithium. The following varieties may be distinguished:

Black, iron tourmaline ($Fe_4Na_2B_6Al_{14}H_8Si_{12}O_{63}$); gravity = 3.2.

Red, green, colorless; alkali tourmaline ($(NaLiK)_4B_6Al_{16}H_8Si_{12}O_{63}$); gravity = 3.

Brown; colorless; magnesium tourmaline ($Mg_{12}B_6Al_{10}H_8Si_{12}O_{63}$); gravity = 3.

Green; chromium tourmaline (chromium replacing a portion of the aluminium); gravity = 3.1.

Transparent crystals (No. 3788) are often differently colored at the different ends, and some are banded with two or three different shades of color, as may be observed in a section parallel to the base.

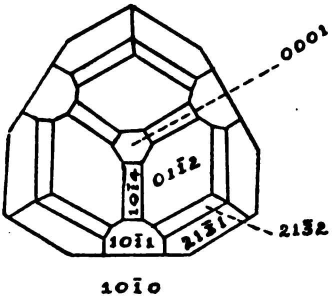


FIG. 213.—Tourmaline, analogous end.

Early in the eighteenth century it was discovered that red tourmaline crystals brought from Ceylon when heated became positively electrified at one end and negatively at the other. When any tourmaline crystals after heating are beginning to cool, if they are dusted with finely powdered red lead (+) and sulphur (−), one end—the negative, the "analogous end"—attracts the red lead, while the other—the positive or "antilogous end"—attracts the sulphur. The negative end (No. 3791) usually shows a basal plane and the rhombohedron (*R*) over the trigonal prism (1010) (Fig. 213). The positive end is usually acute owing to the development of pyramids. All tourmalines absorb the ordinary ray much more completely than they do the extraordinary, consequently black varieties look green or blue with the ordinary ray (*o*) and brown or red with the extraordinary (ϵ). Brown crystals cut parallel to the optic axis transmit only the extraordinary ray, and can be used as polarizer and analyzer. Two such sections held in wire rings constitute "tourmaline tongs."

Summary

Tourmaline.—$(FeCrNaKLi)_4Mg_{12}B_6Al_{16}H_8Si_{12}O_{63}$. Hexagonal; symmetry ditrigonal polar; $a:c = 1:0.4477$. (0001), $(10\bar{1}1)$, $(02\bar{2}1)$, $(10\bar{1}0)$, $(11\bar{2}0)$, $(32\bar{5}1)$. Cleavage imperfect parallel $(10\bar{1}1)$. Brittle; fracture subconchoidal.

Hardness = 7; gravity = 3.1. Black, brown, red, green, colorless; vitreous; translucent; $\omega = 1.64$. Double refraction strong, negative; $\omega - \epsilon = 0.017$. Pleochroic; pyro-electric.

Fusible; insoluble.

Maine to California, Urals, Alps.

ZEOLITE GROUP

The zeolites (ζέω, "I boil") are white, pearly, light (gravity, 2), soluble minerals, which boil before the blowpipe because the two to six molecules of water of crystallization contained in them are loosely held. The different members of the group are so-called "secondary minerals" since they result from the decomposition of other minerals, chiefly feldspar, leucite, etc., in disintegrating igneous rocks. From seventeen representatives three may be chosen to indicate the nature of the group.

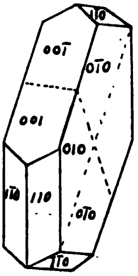


FIG. 214.—Four-twinned crystals of stilbite.

FIG. 215.—Stilbite sheaf

Stilbite

The most attractive characteristic about this mineral is its pearly sheaflike crystals (Nos. 3255 and 3514), which result from twinning of monoclinic crystals parallel to the base and orthodome in such a manner as to produce interpenetrating twins. The crystals are flattened parallel to the clinopinacoid, which is also a plane of easy cleavage. The basal cleavage is imperfect. The basaltic rocks found in many places in New Jersey, Michigan, the Cordilleras, Scotland, etc., contain in their cavities fine groups of stilbite crystals.

SUMMARY

Stilbite.—$CaAl_2Si_6O_{16}+6H_2O$; $CaO=8.94$ per cent, $Al_2O_3=16.31$ per cent, $SiO_2=57.51$ per cent, $H_2O=17.24$ per cent. Some Na_2 usually replaces a portion of the Ca. Monoclinic; $a:b:c=0.7623:1:1.1940$. $\beta=50°50'$ (001), (010), (110). Twinned parallel (001) and ($\bar{1}01$). Cleavage parallel (001). Brittle; fracture uneven.

Hardness $=3.5$; gravity $=2.2$. White; vitreous; transparent; $\beta=1.498$. Double refraction, strong, negative; $\gamma-\alpha=0.006$. Axial plane (010) acute bisectrix inclined 85° to normal of (001) and 34° to the normal of (100). $2E=51.5$.

Fusible (2.5). Decomposed by hydrochloric acid.

In disintegrating igneous rocks in the Cordilleras, Appalachians Scotland, etc.

Analcite

The second representative of the zeolites to claim our attention is analcite (No. 3576), one of the best illustrations of the trapezohedral crystals among minerals (Fig. 216). More rarely analcite occurs in cubes with corners truncated by the trapezohedrons. Small crystals are often beautiful and glossy. The larger ones are usually opaque and white or pink.

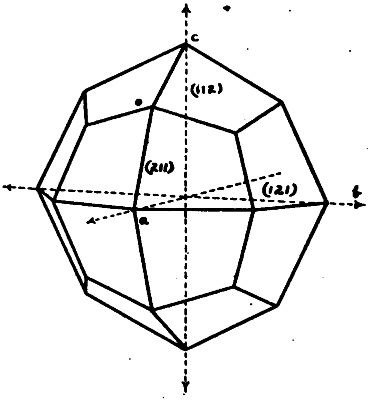


FIG. 216.—Leucite

SUMMARY

Analcite.—$Na_2Al_2Si_4O_{12}+2H_2O$; $Na_2O=14.1$ per cent, $Al_2O_3=23.2$ per cent, $SiO_2=54.5$ per cent, $H_2O=8.2$ per cent. Regular; (211), (100). Brittle; fracture uneven.

Hardness $=5.5$; gravity $=2.2$. Colorless; vitreous; transparent. $n=1.487$.

Fusible (2.5). Gelatinizes in hydrochloric acid.

Same regions as other zeolites.

Natrolite

Natrolite (No. 3517) is closely related to analcite in chemical composition inasmuch as it contains one less molecule of SiO_2, but differs markedly in form since it crystallizes in the orthorhombic system and occurs in long prisms that end in very flat pyramids.

It is the commonest of fibrous zeolites, usually constituting masses in cavities. Beautiful tufts of acicular crystals are found in the cavities of basalt.

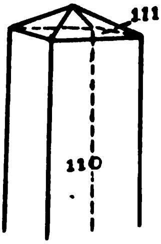


FIG. 217.—Natrolite

So fusible is it that it melts in a candle flame, imparting the yellow color characteristic of burning sodium.

SUMMARY

Natrolite.—$Na_2Al_2Si_3O_{10} \cdot 2H_2O$; $Na_2O = 16.32$ per cent, $Al_2O_3 = 26.86$ per cent, $SiO_2 = 47.36$ per cent, $H_2O = 9.46$ per cent. Orthorhombic; $a:b:c = 0.978:1:0.354$. (110), (111). Cleavage parallel (110) perfect. Brittle; fracture uneven.

Hardness = 5.5; gravity = 2.2. Colorless; vitreous; transparent. $\beta = 1.479$. Double refraction positive, strong; $\gamma - \alpha = 0.012$. Axial plane (010). Acute bisectrix normal to (001). $2_{,}E = 99°$; $\rho < \nu$.

Fuses readily (2). Gelatinizes in hydrochloric acid.

In basalts in the Cordilleras, Michigan, New Jersey, etc.

MICA GROUP

While zeolites are comparatively rare, the members of the mica group are among the most abundant, well-known, and useful of minerals. The thin, flexible, elastic leaves into which mica may be separated distinguish it so clearly that once seen it is not forgotten.

From the seven members of the group the three most striking and abundant are white mica, muscovite, "isinglass"; black mica, biotite; and lilac mica, lepidolite.

Together with quartz and feldspar, micas are common in the granites, gneisses, and schists. The minerals of this group are always crystallized and never massive. The crystals vary from minute flakes to immense sheets which measure sometimes several feet across. In some localities in Russia, India, Canada, and the United States, deposits are being mined which furnish sheets of large size.

The crystals are flat monoclinic prisms having six sides and often so regularly shaped as to appear to belong to the hexagonal or orthorhombic system (Fig. 218). Accurate measurements and optical investigations, however, reveal their monoclinic symmetry. The angles between the prism planes are always about 120°.

The micas are all silicates of aluminium and of either potassium, sodium, and lithium—the alkali micas—or of iron and magnesium—the ferro-magnesium mica; and contain also fluorine and hydrogen.

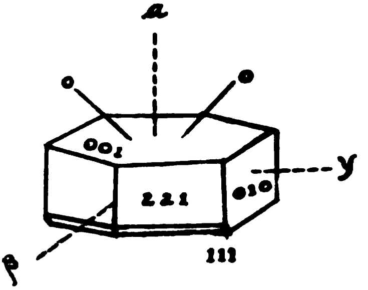


FIG. 218.—Muscovite

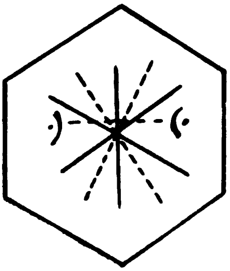


FIG. 219.—Muscovite: pressure figure dotted; percussion figure solid; optic axes.

Inclusions of other minerals, such as hematite, tourmaline, garnet, etc., are common and are arranged as flat scales along definite lines marked out by the so-called glide planes. When minute they often produce the attractive property known as asterism.

Muscovite

White mica is called muscovite, from Moscow, where it and a substance resembling it in appearance—gelatin, derived from the sturgeon so abundant in Russian rivers—were long used for window panes and other purposes. It is the potassium mica, $H_2KAl_3(SiO_4)_3$. Its crystals often attain large size. They are six-sided, rough-faced, and taper because of the dome planes (Nos. 3519, 3520, 378, 1281). Besides the excellent cleavage parallel to the base (001), no other cracks are apt to be found in thin sections. But by pressure with a blunt-pointed instrument three sets of cracks (the dotted line in Fig. 219), the so-called pressure figures, are formed. The cracks correspond to the glide planes which are parallel to the clinodome ($\bar{2}05$) and the pyramid (135). When developed in nature these cracks divide the crystal into trigonal pieces.

The percussion figure produced by striking a cleavage plate with a sharp-pointed instrument consists of a six-rayed star in which the rays intersect at angles of 60° (the solid lines in Fig. 219). The most prominent crack is parallel to the brachypinacoid (010), which is the plane of symmetry.

In muscovite the axial plane is perpendicular to the principal crack of the percussion figure and hence parallel to the macropinacoid (100). Hence muscovite is called "macrodiagonal mica" or mica of the first class.

Muscovite is formed both in fused magmas and in aqueous solutions.

Its uses are many: by the Russians for windows in war vessels, by the French for decoration and ornamentation, by the Anglo-Saxons for various commercial purposes. It furnishes doors for stoves and furnaces. It is used for electrical purposes. It serves as a non-conductor of heat and electricity. It is an absorbent of nitroglycerine; it is a lubricant. In short, it is a mineral much used by man.

SUMMARY

Muscovite.—$H_2KAl_3(SiO_4)_3$; $K_2O=11.8$ per cent, $Al_2O_3=38.5$ per cent; $SiO_2=45.2$ per cent, $H_2O=4.5$ per cent. Monoclinic; $a:b:c=0.5777:1:3.312$. $\beta=89° 54'$. (001), (111), (221), (110), (010). Twins parallel (110) are combined on the base (001). Cleavage parallel (001). Elastic; fracture uneven; chief percussion figure parallel to (010).

Hardness=2.5 per cent; gravity=2.86. Axial plane perpendicular to (010); $\beta=1.6$. Double refraction negative, strong; $\gamma-\alpha=0.039$; $\rho>v$. Pleochroism feeble; transparent, white; vitreous.

Fusible with difficulty; insoluble.

In granites, gneisses, mica schists, in all mountain ranges. New Hampshire, South Carolina, South Dakota, Colorado, New Mexico, and California.

Biotite

Black mica, named biotite after Biot, the celebrated French mineralogist, is the magnesian mica $(H,K)_2(Mg,Fe)_2Al_2(SiO_4)_3$ (Nos. 3535, 3536, 1240, 1768, 453).

In this mica the axial plane is usually parallel to the chief percussion figure, which, as noted above, is parallel to the brachypinacoid (010). Such biotite is said to be a brachydiagonal mica, or mica of the second class.

Whether muscovite or biotite is the more abundant mica is difficult to say, since both abound in nearly all kinds of igneous rocks. Biotite decomposes more readily than muscovite and forms such minerals as chlorite, epidote, quartz, and iron oxide. Its characteristic color is black, but while undergoing decomposition it assumes red and green shades. It is strongly pleochroic and apparently uniaxial. Fine crystals are found at Vesuvius.

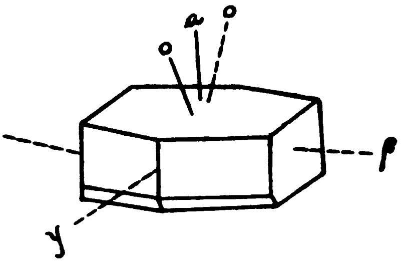


FIG. 220.—Biotite; axial plane parallel to (010).

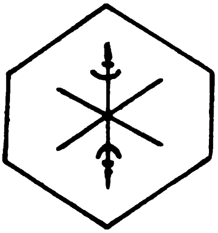


FIG. 221.—Basal section of biotite, showing position of axial plane and percussion figure.

SUMMARY

Biotite.—$(H,K)_2(Mg,Fe)_2Al_2(SiO_4)_3$; $K_2O=7.64$ per cent, $MgO=21.89$ per cent, $H_2O=4.02$ per cent, $F=0.89$ per cent, $Fe_2O_3=7.86$ per cent, $Al_2O_3=16.95$ per cent, $SiO_2=39.30$ per cent. A little FeO, MnO, CaO, and Na_2O are usually present. Monoclinic; $a:b:c=0.577:1:3.274$. $\beta=90°$. (110), (111), (001), (010), (221). Twinning plane parallel to (110), combination face (001). Cleavage parallel to (001) perfect; laminae elastic; fracture uneven.

Hardness $=2.5$; gravity $=2.86$. Black, pleochroic; a green, β and γ dark brown. Translucent; luster vitreous; streak colorless. Plane of optic axes parallel to (010). Acute bisectrix inclined 30′ to the perpendicular of (001). $\beta=1.6$. Double refraction negative, strong; $\gamma-\alpha=0.04$; $\rho<\nu$; $2E=12° 48'$.

Fusible with difficulty; soluble in sulphuric acid.

Maine, North Carolina, Colorado.

Lepidolite

This beautiful violet mica (No. 553) occurs in small flakes only (λεπις, "scale"). It is usually accompanied with other lithium minerals such as tourmaline. The violet color is probably due to manganese. San Diego, California, has within the last few years supplied most of the museums of the country with fine specimens of lepidolite.

SUMMARY

Lepidolite.—$Li_2K_2F_2Al_3H_2Si_6O_{20}$; $Li_2O = 1$ to 6 per cent, $K_2O = 4$ to 10 per cent, $F = 2$ to 8 per cent, $Al_2O_3 = 26$ to 33 per cent, $SiO_2 = 49$ to 52 per cent. Monoclinic; crystallographic and optical properties similar to those of the other micas, but the axial plane is sometimes parallel and sometimes perpendicular to the plane of symmetry.

Hardness = 2.5; gravity = 2.8. Lilac or rose-colored.

Partly soluble in hydrochloric acid.

Maine, Massachusetts, Connecticut, California.

SERPENTINE AND TALC GROUP

These two magnesian silicates are common decomposition products of other ferro-magnesian silicates. They are basic salts and not hydrated, inasmuch as they part with their water at high temperatures only. Like most secondary minerals they are soft. Crystallization is inconspicuous. They occur most commonly in compact masses in veins or beds.

Serpentine

Serpentine is a green, red, or yellow mineral often more or less fibrous in structure, as may be seen under the microscope in those masses which fill veins. At times the fibers are well pronounced and silky in luster, and the mineral is then called chrysotile—the most abundant asbestos (No. 3540). The fibers are longer, more tenacious and silky than those of the amphibole asbestos. The most productive asbestos mines in North America, those in Megantic and Beauce counties, Quebec, furnish the chrysotile variety of asbestos. Arizona, California, and Wyoming are furnishing small quantities.

Some serpentines supply ornamental stones of great beauty (Nos. 4336, 4337). The permanent dark-green color is rendered even more attractive by white particles of magnesite and talc, and by splashes of blood-red iron stains. "Verde antique" is a brecciated serpentine.

SUMMARY

Serpentine.—$H_4Mg_3Si_2O_9$; MgO = 43.5 per cent, SiO_2 = 43.5 per cent, H_2O = 13 per cent. Massive; fracture splintery.

Hardness = 3; gravity = 2.6. Green; luster greasy; translucent; $\beta = 1.57$. Double refraction negative, weak; $\gamma - \alpha = 0.010$.

Fusible with difficulty (6). Soluble in hydrochloric acid.

Appalachians, Cordilleras, Alps, etc.

Talc

Talc is a foliated, silvery, soft, greasy mineral. Though the flakes show hexagonal outline, yet, like mica, talc is monoclinic. The angle between the optic axes is very small. In many regards talc resembles one of the micas, phlogopite, but is softer and not elastic (Nos. 353, 368). Talc usually contains from 1 to 4 per cent of iron oxide.

The compact varieties, such as steatite or soapstone, were used by the Chinese in ancient times for ornaments and images, and by savage and civilized peoples today. A clearer conception of the value of the mineral industry in the United States may be gained by the knowledge that while talc is a mineral rarely mentioned, more than a million dollars' worth of it are produced in the United States annually and manufactured into such articles as bath and laundry tubs, sinks, mantles, hearthstones, fire brick, griddles, slate pencils, gas tips, crayons, French chalk for tailors, adulterant for sugars, lubricators for dressing skins and leather, toilet powders, dynamite, paper-making, pigments in high-grade paints, etc. New York is the leading state in the production of talc and Virginia in soapstone.

SUMMARY

Talc.—$H_2Mg_3(SiO_3)_4$; MgO = 31.7 per cent, SiO_2 = 63.5 per cent, H_2O = 4.8 per cent. Monoclinic. Cleavage parallel (001) perfect; sectile, pliable.

Hardness = 1; gravity = 2.7. Color silver white; luster pearly; translucent. $\beta = 1.55$. Double refraction negative, strong; $\gamma - \alpha = 0.040$. Acute bisectrix normal to the cleavage. $2E = 19°$.

Almost infusible. Insoluble.

The Alps, Appalachians, Cordilleras, etc.

Kaolinite

Decomposition of orthoclase, albite, leucite, beryl, and other minerals often gives rise to a secondary mineral, kaolinite, which is a hydrated aluminous silica, $H_4Al_2Si_2O_9$. The pure form is kaolinite (from the Chinese *kaoling*, "high ridge"). As various impurities such as iron, calcium, and magnesium increase, various clays result. In structure and other physical characters kaolinite resembles the hydrated magnesian silicate serpentine. It is white, scaly, flexible, inelastic, soft (hardness, 2), light, (gravity, 2.6), unctuous, and plastic.

Some clays have absorbent properties which render them valuable as fuller's earth. Others fuse at such temperatures and yield a product of such character as to be valuable for porcelain, china, tile, brick, etc. Others are plastic because of the elongated particles which constitute them, and are useful in clay-modeling.

Various varieties of clays are among the most abundant mineral constituents of the regolith covering Illinois. They form soil for agriculture and plastic material for the manufacture of tile, porcelain, brick, etc. Their contribution thus to the wealth of the state is difficult to estimate. The value of clay products sold annually in this state amounts to more than fifteen million dollars, but this takes no account of the return through soil fertility. Clay soils are useful chiefly in furnishing a binder for more porous soil, as retaining moisture, and as being a container for other plant food.

SUMMARY

Kaolinite.—$H_4Al_2Si_2O_9$; $Al_2O_3=39.5$ per cent, $SiO_2=46.5$ per cent, $H_2O=14$ per cent. Water is driven off at 330°. Monoclinic. Scales flexible, inelastic; friable to compact; unctuous, plastic.

Hardness=2.5; gravity=2.6. White, blue, yellow, red, green; luster pearly to earthy; translucent. Biaxial, negative.

Infusible; insoluble. Blue color with cobalt solution.

Many eastern and middle states, such as Massachusetts, Delaware, Georgia. Illinois, etc.

PLATE XXIX

a, Apatite, Renfrew, Canada

b, Barite, Alston Moor, England

CLASS VIII. NIOBATES, TANTALATES

CLASS IX. PHOSPHATES, ARSENATES, VANADATES, ANTIMONATES, NITRATES

Apatite

Apatite is a mineral of great commercial importance, occurring in metamorphic limestones and in granites often as well-formed crystals (No. 3551) varying from microscopic size to dimensions of a foot or more (Plate XXIX*a*). As usual, the more nearly perfect crystals with well-terminated ends occur in cavities. Their prevailing color is blue, green (No. 3550), yellow, or brown. Among the most beautiful apatite crystals found are little limpid hexagonal prisms contained in crystalline schists in the St. Gothard and Untersultzbachthal. Microscopic crystals are found in a variety of igneous rocks. The planes most commonly appearing (Fig. 222) are the following: $(10\bar{1}0)$, $(11\bar{2}0)$, $(10\bar{1}1)$, (1121), (0001). The prisms are usually vertically striated. Apatite resembles beryl in appearance, but is softer, has imperfect cleavage parallel to the base, and a high, refractive index.

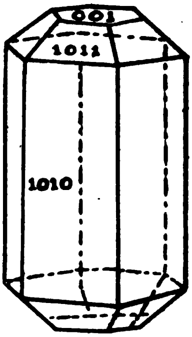


FIG. 222.—Apatite

Chemically there are two varities of apatite: the ordinary, which contains fluorine; and the less common, in which fluorine is replaced by chlorine. According to physical condition there are two kinds which are even more markedly different than are the two chemical varieties. The first is pure crystallized apatite, which is found filling veins and as inclusions in metamorphic rocks (Nos. 3666, 3709, 3712). The second is phosphorite (No. 4307), the white, structureless variety, organic in origin and occurring in extensive beds in the Carolinas and Tennessee. It has resulted by the concentration of phosphatic material which was previously disseminated through sands and sandstone.

The crystallized apatite is found in most of the Appalachian states and in the drifts over the middle states in granular limestone and in granites, gneisses, and schists, and in veins in iron ores.

Apatite is one of the most important of all minerals to man, inasmuch as it is the chief source of phosphorus, a chemical substance indispensable to plant growth.

SUMMARY

Apatite.—$Ca_5F(PO_4)_3$; $CaO = 55.5$ per cent, $P_2O_5 = 42.3$ per cent, $F = 3.8$ per cent. Hexagonal; symmetry hexagonal equatorial; $a:c = 1:0.7346$. $(10\bar{1})$, $(10\bar{1}1)$, $(11\bar{2}1)$, $(21\bar{3}1)$. Cleavage parallel to (0001), $1\bar{0}10$). Brittle; fracture conchoidal.

Hardness = 5; gravity = 3.2. Colorless; luster vitreous; transparent; $\omega = 1.646$. Double refraction negative, weak; $\omega - \epsilon = 0.004$.

Fusible with difficulty; soluble in hydrochloric acid.

Ottawa County, Quebec, Canada; Bolton, Massachusetts; Crown Point, New York; New Jersey.

Pyromorphite

Pyromorphite (No. 507) is a lead chloro-phosphate found in quantities in upper levels of lead mines, where it has been forming during the decomposition of lead sulphide. It was named pyromorphite because, when fused before the blowpipe, upon cooling it solidifies with many facets (πῦρ, "fire"; μορφη, "form"). These facets are not true crystal faces. The true crystals are composed of prisms and basal planes which produce barrel-shaped forms because of aggregation and curvature of the prisms. A violet color is shown by large hexagonal prisms occasionally, but the prevailing color is green or brown.

SUMMARY

Pyromorphite.—$Pb5Cl(PO_4)3$; $PbO = 82.3$ per cent, $P_2O_5 = 15.7$ per cent, $Cl = 2.6$ per cent.

Hexagonal; symmetry hexagonal equatorial. (1010), $(10\bar{1}1)$, (0001). Cleavage parallel $(10\bar{1}0)$, $(10\bar{1}1)$ imperfect. Brittle; fracture subconchoidal.

Hardness = 3.5; gravity = 7. Green; luster resinous. Translucent; $\omega = 1.50$. Double refraction negative, weak; $\omega - \epsilon = 0.006$.

Easily fusible (1.5). Soluble in nitric acid.

Missouri, Wisconsin, Colorado, New Mexico, and Australia.

CLASS X. BORATES, URANATES

Borax, Colemanite, Boracite

These three borates are of importance as the source of boron compounds which are useful as antiseptics, medicines, cosmetics, and welding compounds. All of them are most commonly met with in arid regions in connection with salt lakes, past or present. Crystals of colemanite and boracite are often beautiful because of their transparent character and lustrous surfaces.

SUMMARY

Borax.—$Na_2B_4O_7 . 10H_2O$; $Na_2O = 16.2$ per cent, $B_2O_3 = 36.6$ per cent, $H_2O_2 = 47.2$ per cent. Monoclinic, prismatic class; $a:b:c = 1.09:1:0.562$; $\beta = 73°$; (100), (110), (001), (111). Cleavage perfect (100); fracture conchoidal.

Hardness = 2; gravity = 1.7. White, vitreous, translucent; $\beta = 1.47$. Double refraction negative; $\gamma - \alpha = 0.004$; acute bisectrix normal to (010); $2\ E = 59°$; $\rho > \nu$.

Fusible, swells up; soluble in water; sweetish.

Thibet, Peru, California, Nevada.

Colemanite.—$Ca_2B_6O_{11} . 5H_2O$; $CaO = 27.2$ per cent, $B_2O_3 = 50.9$ per cent, $H_2O = 21.9$ per cent. Monoclinic, prismatic class; $a:b:c = 0.77:1:0.541$; $\beta = 70°$; (110), (301), (100), (010), (001), (111), (021), (221). Cleavage (010); fracture uneven.

Hardness = 4; gravity = 2.4. Colorless, white; translucent, vitreous; $\beta = 1.5902$.

Fusible, exfoliates; soluble in hot hydrochloric acid; insoluble in water.

California, Chile.

Boracite.—$Mg_5(MgCl)_2B_{16}O_{30}$; $MgO = 31.4$ per cent, $Cl = 7.9$ per cent, $B_2O_3 = 62.5$ per cent. Dimorphous; crystals formed above 265° C., regular; below that, orthorhombic; (110), (100), (111), (111), (211). Cleavage (111) imperfect; brittle; fracture conchoidal.

Hardness = 7; gravity = 3. Colorless, vitreous, translucent. Double refraction; $\beta = 1.667$; $\gamma - \alpha = 0.011$; $2\ V = 90°$.

Fusible, swells up; soluble in hydrochloric acid.

Stassfurt, Prussia.

Uraninite

The uranate uraninite is of interest because it is a source of uranium, of radium, and of helium. Its composition is doubtful, inasmuch as a large number of rare elements are present. In addition to oxides of uranium, thorium, lead, iron, and calcium, small quantities of the following have been found: zirconium, cerium, lanthanum, didymium, yttrium, erbium, helium, manganese, sodium, potassium, silicon, phosphorus, and hydrogen. Its composition may be expressed by the formula U_3O_8. Uranium compounds are used in the laboratory for the determination of phosphorus and zinc, in the manufacture of pigments, glazes, and special steels.

SUMMARY

Uraninite.—U_3O_8. Regular, (111), (110), (100). Crystals rare, crystalline masses, botryoidal groups. Brittle; fracture conchoidal.

Hardness = 5.5; gravity = 9.5. Brown, black; luster dull.

Infusible; soluble in nitric and sulphuric acids; radio-active.

Colorado, Cornwall, Austria.

CLASS XI. SULPHATES, CHROMATES, TELLURATES

Class XI, containing the sulphates, chromates, and tellurates, is an outstanding class because of at least four commercially and scientifically interesting minerals, namely, barite, celestite, anglesite, and gypsum.

Barite

Barite, or heavy spar (βαρύς, "heavy"), so named since it is nearly twice as heavy as other white minerals like calcite or gypsum, is important because of its fine crystals, its great masses, and its usefulness.

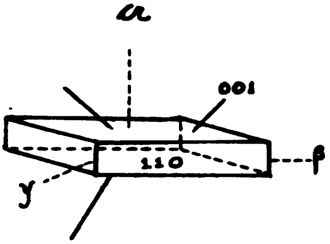


FIG. 223.—Barite

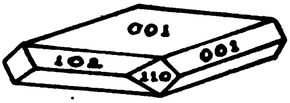


FIG. 224.—Barite

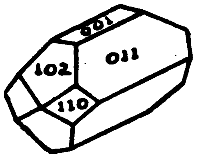


FIG. 225.—Barite

The crystals are usually flat (Nos. 3562 and 3556), and consist of large basal planes with short prisms, as in Figure 223. Forms composed of dome planes elongated parallel to the *a* axis (Fig. 224) are not uncommon (No. 4060). Cleavage pieces take the form of Figure 225, and the position of the axes is indicated by the cleavage, which usually shows pearly cracks. Prismatic cleavage is good. Aggregates of crystals produce rounded masses from which acute prism edges protrude. Radiated, columnar, and massive (No. 3559) forms are common, though a white, earthy, massive condition is most characteristic. Discoloration by iron is usual.

Inorganic phosphorescence was first discovered when an Italian investigator in the early part of the seventeenth century heated barite on charcoal and noticed that in the dark it continued to emit a glow, due to the reduction of the sulphate to sulphide.

Barite is found in veins and masses with ores of lead, antimony, and iron in limestones, especially in Georgia, Missouri, and Tennessee.

It is used in the manufacture of white paint, filler for paper, barium for chemical and medicinal uses, etc. Nearly four hundred thousand dollars' worth of barite was produced in the United States in 1915.

SUMMARY

Barite.—$BaSO_4$; $BaO=65.7$ per cent, $SO_3=34.3$ per cent. Orthorhombic; $a:b:c=0.815:1:1.314$. (001), (110), (102), (011), (122), (111). Cleavage parallel (110) and (001) perfect; brittle; fracture uneven.

Hardness=3; gravity=4.5. Colorless; luster vitreous; transparent; $\beta=1.637$. Double refraction positive, strong; $\gamma-\alpha=0.012$. Axial plane (010); acute bisectrix perpendicular to (100); $2E=64°$; $\rho<v$.

Fusible (3) with decrepitation; insoluble in acid.

Georgia, Missouri, Tennessee, Kentucky.

Celestite

The next member of the group is the strontium sulphate, celestite, so named (coelestinus, "blue") since the first crystals discovered (in Pennsylvania) exhibited delicate blue shades, due, no doubt, to the presence of traces of iron phosphate. The crystals are inclosed by a variety of planes. While barite is more often elongated along the *a* axis, the elongation of celestite takes place parallel to the *b* axis. The massive forms are common in limestone, marl, sandstone, and beds of gypsum.

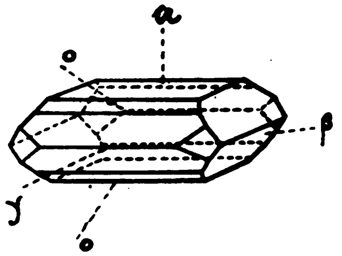


FIG. 226.—Celestite (001), (104), (102), (110), and (011).

Sicily; Strontian, Scotland; North Bass Island, Lake Erie; Pennsylvania, Kansas, Texas, West Virginia, and Tennessee contain supplies of this mineral, which together with strontianite are the chief sources of strontium nitrate, a compound much used to produce the crimson colors in fireworks.

SUMMARY

Celestite.—$SrSO_4$; $SrO = 56.4$ per cent, $SO_3 = 43.6$ per cent.

Orthorhombic; $a:b:c = 0.779:1:1.280$. (001), (110), (011), (102), (104). Cleavage parallel (001) perfect; parallel (110) good. Brittle; fracture uneven.

Hardness = 3; gravity = 3.9. Colorless; luster vitreous; transparent; $\beta = 1.624$. Double refraction positive, weak; $\gamma - \alpha = 0.009$. Axial plane parallel (010). Acute bisectrix perpendicular to (100). $2E = 88° 38'$.

Fusible (3) with decrepitation. Insoluble in acids.

Lake Erie, Pennsylvania, New York, Kansas, Texas, West Virginia, Tennessee.

Anglesite

Lead sulphate ($PbSO_4$) crystals resemble barite and celestite in being flat (No. 3563). They are elongated not only parallel to the *b* axis but also quite commonly parallel to the *c*. They were first found on the island of Anglesy, and many localities now furnish fine, lustrous, transparent, colorless crystals which line the cavities in glistening, granular galena. The lead mines of Missouri, Wisconsin, Kansas, Colorado, Mexico, and Australia furnish this mineral in massive varieties and in such quantities as to render it an important ore of lead.

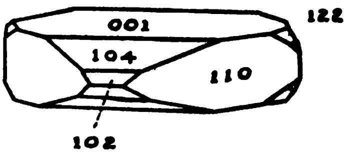


FIG. 227.—Anglesite

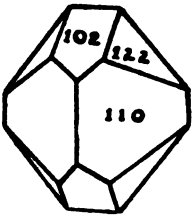


FIG. 228.—Anglesite

Its easy fusibility (1.5), adamantine luster, and great weight (gravity, 6.3) render it easy of determination.

SUMMARY

Anglesite.—$PbSO_4$; $PbO = 73.6$ per cent, $SO_3 = 26.4$ per cent. Orthorhombic; $a:b:c = 0.785:1:1.289$. (110), (001), (011), (102), (104), (122), (111), cleavage parallel (110) and (001) fair. Brittle; fracture conchoidal.

Hardness=3; gravity=3.6. Colorless; luster adamantine; transparent; $\beta=1.883$. Double refraction positive, strong; $\gamma-\alpha=0.016$. Axial plane parallel (010). Acute bisectrix perpendicular to (100). $2H=89^\circ 52'$; $\rho<v$.

Easily fusible (1.5). Soluble in nitric acid with difficulty.

Missouri, Wisconsin, California, Mexico, and Australia.

Barite, celestite, and anglesite constitute a fine example of an isomorphous group, with simple, bright, glassy, tabular or prismatic orthorombic crystals which cleave parallel to the base (001) and prism (110). The optical characteristics are all similar.

Gypsum

The next sulphate of importance is the hydrated calcium sulphate gypsum. This is a mineral vastly more abundant than all the other members of the group combined. The name gypsum was used by the Greeks (γύψος). Dioscorides and Pliny called it "selenites," from which our word "selenite" is derived, which is now restricted to lustrous, satiny, crystallized gypsum. Near Paris (Montmartre) gypsum was early quarried, ground, and burned for plaster and hence was named plaster of Paris. When used upon the fields as a fertilizer it is called land plaster. When translucent, compact, and suitable for carving, it is called alabaster. Satin spar is composed of compact fibers, with the luster of satin, and is used for cheap jewelry. It is

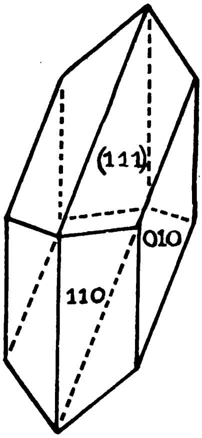


FIG. 229.—Gypsum

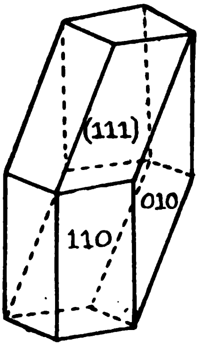


FIG. 230.—Gypsum

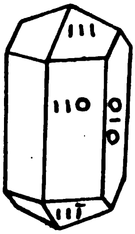


FIG. 231.—Gypsum

PLATE XXX

Gypsum, showing fishtail twin and curled form

PLATE XXXI

Gypsum, "selenite," Wayne County, Utah

easy to work but even more easy to destroy, since it is so soft that it has slight value.

The chief use of gypsum, however, is as plaster of Paris. When ground and burnt, it loses its water of crystallization, then upon being mixed with water again it takes up the lost molecules, and recrystallizes or "sets" ($CaSO_4 \cdot H_2O$).

The greatest quantities are now mined in Michigan (No. 3523), New York, Virginia, Ohio, Iowa, Alabama, Arkansas. For hundreds of miles beds of gypsum may be seen stretching like a white ribbon over the country in Wyoming, Colorado, and many other Cordilleran states.

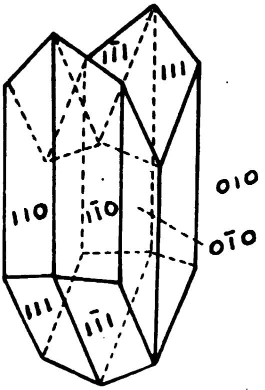


FIG. 232.—Gypsum, twinned by juxtaposition parallel (100).

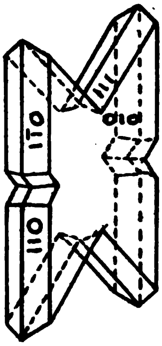


FIG. 233.—Gypsum, twinned by interpenetration parallel (100).

Crystals sometimes several feet long are found (No. 4058). In Utah a few years ago a huge geode was discovered whose walls were covered with gigantic transparent crystals. Many of them now adorn the museums of this and other countries (Nos. 3890, 4308, 4498) (Plate XXXI). Multitudes of excellent crystals have been obtained at Girgenti, Sicily (No. 3567); Bex, Switzerland; Montmartre, France; Oxford, England (No. 3535). See Figures 229 to 233. Large transparent crystals from Kansas and Colorado, imperfect in outline, yield beautiful cleavage pieces. The cleavage parallel to the clinopinacoid (010) is so perfect that plates of any desired thickness may be obtained and used under a microscope to detect the weak double refraction of some minerals. For example, if a plate of such thickness as to yield red of the first order between crossed nicols is used, it will become blue when the thin section under examination is positive (since gypsum is positive). In this case the color is raised. It becomes yellow, that is, depressed, when the mineral is negative.

There are two other cleavages also, one with a fibrous surface parallel to an orthodome $(\bar{1}01)$, and one with conchoidal surface parallel to the orthopinacoid (100). Cleavage lines aid in orienting crystals that are without crystal faces.

Twinning is parallel to the orthopinacoid (100) both by juxtaposition (Fig. 232) and by interpenetration (Fig. 233). The fibrous cleavage cracks parallel to the orthodome do not run uniformly across the crystal, but meet at an angle of 47°50′ on the line of contact.

The crystals are often curved or lenticular. (See Plate XXX.)

SUMMARY

Gypsum.—$CaSO_4 \cdot 2H_2O$; $CaO = 32.5$ per cent, $SO_3 = 46.6$ per cent, $H_2O = 20.9$ per cent. Monoclinic; $a:b:c = 0.690:1:0.412$. $\beta = 80°42'$. (010), (111), (110), (130), $(\bar{1}03)$. Twinned on (100), also on (101). Cleavage parallel (010) perfect; parallel (100) and (101) imperfect; parallel (100) and $(10\bar{1})$ imperfect. Sectile; flexible.

Hardness = 2; gravity = 2.3. Colorless; luster vitreous; transparent; $\beta = 1.522$. Double refraction positive; $\gamma - \alpha = 0.010$. Axial plane parallel (010). Acute bisectrix inclined 37° 30′ to the normal of (100), and 43° 12′ to the normal of (001). $2E = 95°$. $\rho > \nu$. Inclined dispersion.

Easily fusible (3). Soluble in hydrochloric acid.

Michigan, New York, Virginia, Ohio, Iowa, Alabama, Arkansas, and the Cordilleran states.

CLASS XII. TUNGSTATES, MOLYBDATES

The class of tungstates and molybdates contains but few minerals and those few are of slight importance. One example of each may be considered: the tungstate, wolframite; and the molybdate, wulfenite.

Wolframite

Wolframite (No. 3533), a black mineral accompanying cassiterite in tin-bearing regions, and greatly resembling cassiterite in appearance, is the chief source of tungsten, an element being used in an increasing degree in manufactures. Well-formed monoclinic crystals resembling those shown in Figure 234 are common, but bladed, lamellar, or granular forms are more abundant. Its perfect cleavage parallel to (010) and its stibnite-like luster aid in distinguishing it, although otherwise it is a somewhat difficult mineral to identify, since blowpipe reactions for tungsten are masked by the presence of the iron and manganese in its formula, (FeMn)WO_4. After wolframite is boiled in aqua regia, tungstic oxide appears as a yellow residue.

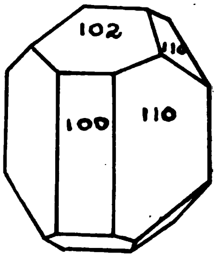


FIG. 234.—Wolframite

Tungsten steel is especially valuable for permanent magnets, cutting tools, wires for electric purposes, etc. Tungsten is also used as a dye which renders cotton less inflammable.

Wolframite is found in veins in Cornwall, Zinnwald, Black Hills, North Carolina, and Missouri.

SUMMARY

Wolframite.—(FeMn)WO_4; FeO varying from 2 to 19 per cent, MnO from 6 to 22 per cent, $WO_3 = 76$ per cent. Monoclinic; holosymmetric. Cleavage parallel (010) perfect, parallel (100) imperfect. Brittle; fracture uneven.

Hardness = 5.5; gravity = 7.3. Black; streak reddish brown; luster metallic; opaque.

Fusible (3) to magnetic bead. Decomposed by hydrochloric acid.

North Carolina, Missouri, South Dakota.

Wulfenite

This molybdate (Nos. 3528 and 3531), $PbMoO_4$, is a heavy, red, resinuous mineral which occurs in granular masses, and often in thin, tabular, square crystals (Fig. 235), or less commonly in acute pyramids (Fig. 236). Were it not so brittle and soft, it would be one of the most prized of gems, since it is beautiful in color and has a high luster. Commercially it is of small value because of its rarity.

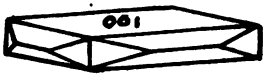


Fig. 235.—Wulfenite

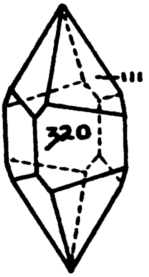


Fig. 236.—Wulfenite

Summary

Wulfenite.—$PbMoO_4$; $PbO=60.7$ per cent, $MoO_3=39.3$ per cent. Tetragonal; symmetry, tetragonal polar. $a:c=1:1.577$. (001), (102), (111), (320). Cleavage parallel (111) good. Brittle; fracture subconchoidal.

Hardness = 3; gravity = 6.7. Red; streak white; luster adamantine; translucent; $\omega=2.402$. Double refraction negative, strong; $\omega-\epsilon=0.098$.

Easily fusible (2); soluble in hydrochloric acid.

Arizona, New Mexico, California, Missouri, Pennsylvania.

CLASS XIII. ORGANIC ACID SALTS

The organic acid salts, oxalates and mellates, which constitute Class XIII are rare and unimportant, hence we may pass at once to the next class.

CLASS XIV. HYDROCARBONS

Though the members of this class are all of organic origin, yet they have been so changed by the loss of some constituent as to rank as mineral substances. Several of them are amorphous. Others retain the structure of the substance from which they were derived. Some of them may be most properly classified as rocks, but since they constitute part of a series they are here included. The most abundant representatives are the fossil resins, asphalt, heavy and light oils, gas, and coal.

Fossil Resins

Amber is a fossil resin occurring in amorphous masses which vary in size from small grains or droplets to chunks a foot or more in diameter. It was exuded from ancient conifers or leguminous trees, and buried by drifting sands in recent geological formations in Spain, Sicily, Germany, etc. It is characterized by conchoidal fracture, softness (hardness, 2), low specific gravity (gravity, 1.1), yellowish to brown color, greasy luster, and translucency. It shows fluorescence, is negatively electric, melts at about 287° and burns with a bright flame and an agreeable odor. It is composed of carbon, hydrogen, and oxygen ($C_{40}H_{64}O_4$); $C=78.93$ per cent, $H=10.55$ per cent, $O=10.52$ per cent. It is used in the manufacture of buttons, beads, pipestems, varnish, amber oil, and acid.

Copal is a kind of amber which contains a larger proportion of hydrogen and melts at a lower temperature (210°). It is slightly harder than amber (hardness, 2.5). It is the dried sap of leguminous and coniferous trees which are found in many parts of the world, such as New Zealand, Australia, Madagascar, the east and west coasts of

Africa, and various places in South America. Nine-tenths of the copal used is obtained from deposits buried sometimes as deeply as twenty feet and often no doubt thousands of years old.

All varieties of amber are used chiefly as material from which to manufacture varnish. Insects imprisoned in the gum as it was exuding from trees have been preserved with remarkable fidelity, so that not only are their most delicate membranes intact, but in many cases an idea of the original color can be obtained.

Asphalt

This hydrocarbon is of indefinite composition. It is black, burns with a pitchy odor and is slightly heavier than water (gravity, 1.1; hardness, 2). It melts at 100° C. and ignites readily with black smoke and bright flame. At a sufficiently low temperature it shows conchoidal fracture. It is soluble in ether.

It occurs in beds or lakes in the island of Trinidad and in veins or disseminated through sandstone or limestone in Kentucky, California, etc.

It forms one of the most satisfactory paving materials when mixed with sand and broken limestone. It is used for roofing, for calking material on ships, for paint on metal and woodwork, and as an adulterant of rubber goods.

Petroleum

Petroleum is one of the most important of mineral substances, being second only to coal and iron in the contribution which it yearly makes to the wealth of mankind. It has been found in many countries, but nowhere so extensively as in the United States. It occurs in strata from the Ordovician to the Pleistocene. It has been produced by the distillation under great pressure of both animal and vegetable substances.

Petroleum, or "rock oil," is composed of a variety of oils, forming a series from the volatile and easily flowing oils to viscous oils, lubricating oils, and greases. It consists chiefly of the paraffines (C_nH_{2n+2}) in Pennsylvania and of the naphthenes (C_6H_{12}) in the Caucasus. The color varies from dark brown to greenish, and the gravity from 0.7 to 0.9. Petroleum shows a distinct fluorescence.

Benzine, naphtha, gasoline, kerosene, lubricating oil, vaseline, dyestuffs, and other chemicals are derived from petroleum.

Pennsylvania long held chief place in the production of petroleum, but recently California has surpassed her, and Ohio, Indiana, Illinois, Kansas, Oklahoma, and Texas have all shown remarkable pools. Mexico and the Caucasus are increasing in productiveness.

Natural Gas

Closely associated with petroleum and having the same origin is natural gas. It too consists mainly of the lower paraffine methane (CH_4) and ethane (CH_3), and also carbon monoxides, carbon dioxide, hydrogen, neon, and the new gas helium, so necessary for war balloons.

Coal

Coal consists of solid hydrocarbons derived from vegetable growths of former geological ages. Trees, shrubs, weeds, mosses, and especially spores of cryptogams contributed to its formation. More than five hundred different species of plants have been identified among those concerned in the production of coal. Among them are six species of algae; two hundred and fifty species of ferns; eighty-three species of lycopods, that is, club mosses whose powder is used for fireworks, medicines, etc.; thirteen species of equisetites, that is, rushes, horsetails, etc.; sixty sigillarids, whose trunks were ribbed and scarred like giant cacti; twelve species of noggerathia with overlapping scales on their trunks and pinnate leaves; forty-four asterophyllites; and three species of cycads, the sago palms.

All of the above were acotyledons, the lowest form of vegetable life. They comprise five-sixths of all the plants which have been identified in coal. The remaining one-sixth were fifteen species of coniferous trees and fifteen of the palms. All of the above-named species are similar to vegetation which thrives in a warm, moist climate today. These plants, grown in swamps or near lakes and rivers, were deposited in beds, buried under mud that later turned to stone, and by the loss of hydrogen and oxygen were converted into coal.

Cross-sections of coal fields in all parts of the country point to such a history. At the bottom of a coal field occurs a conglomerate such as would form on a new shore line. This is covered by sandstone that indicates long action of the waves and gradual decrease in their severity. Next comes shale, and then clay, "fire clay," such as would be formed in the shallow waters of ponds into which sluggish streams carry silt. These are followed by the coal from a few inches to several feet in thickness, such as might be formed in a peat swamp. The lowest coal bed in Illinois is called coal No. 1. This is covered by gray shale showing subsidence of the swamp and burial under mud. Further subsidence brought conditions favorable to formation of sandstone. Re-elevation introduced other shale and fire-clay formations which, in their turn, were followed by swamps in which coal No. 2 was formed. This shifting of the shore line was repeated many times in some localities, as is indicated not only by the different coal seams but also by their containing rocks. There are a dozen different beds in Illinois.

Mollusks, fishes, and amphibians buried in these deposits and changed to stone give further light upon the history of coal.

Coal is found in five geological systems, from the middle Tertiary down through the upper Cretaceous, the lower Jurassic (Oölite), and the Triassic to the Carboniferous. Of these systems the Carboniferous far surpasses all others in production.

In America there are seven extensive coal regions. The first is that included in Acadia, Nova Scotia, New Brunswick, and Rhode Island. The coal measures of Nova Scotia are 7,000 feet thick and contain 76 seams. In Rhode Island and Massachusetts a graphitic anthracite is found.

The second region, covering 70,000 square miles along the Appalachians, includes the famous coal fields of Pennsylvania, Ohio, Maryland, Virginia, West Virginia, Kentucky, Tennessee, and Alabama. In some portions of this field the coal measures are 4,000 feet thick. From no region of the world has more or better anthracite and bituminous coal been obtained.

The third field occupies about 7,000 square miles in Michigan, where the productive Carboniferous is but about 300 feet thick. Indiana and Illinois, with approximately 1,000 feet of Carboniferous strata covering 58,000 square miles, comprise the fourth field—one of the most actively worked and most remunerative.

At one time, continuous with this field was that which now constitutes the fifth field, covering 94,000 square miles. It is found in Iowa, Missouri, Arkansas, and Texas. Here the Carboniferous rocks are thicker than in any other portion of America but not for that reason more promising.

The sixth region is one of scattered character, occurring chiefly in Montana, Wyoming, Colorado, Utah, and Arizona. On the Pacific Coast is the seventh region, embracing Washington, Oregon, and California. Altogether there are more than 335,000 square miles of known coal-bearing territory in North America.

The anthracite area covers less than 1,000 square miles. Half of this is in Massachusetts and Rhode Island, where the anthracite is almost without fuel value because of its graphitic character and consequently no production has been reported in recent years. Colorado contains 15 square miles. Pennsylvania has a field covering 470 square miles. From this latter region practically all the anthracite produced in the United States is obtained. The total coal production in the United States in 1915 was valued at six hundred and eighty-six million dollars. More than a thousand million tons of coal are used in the world each year, and of this amount the United States furnishes the greatest part. Before the world-war Great Britain came next in production, followed in descending order by Germany, Austro-Hungary, France, Belgium, Russia, Japan, India, Canada, New South Wales, Spain, South African Republic, and New Zealand.

Coal was first used in London in 1240. After people had been using it for sixty-six years a law was passed against it on account of the smoke, which was declared to spoil ladies' complexions and clothes! As early as 1552 men began to fear all the coal in the world would soon be exhausted! In 1698 the first mention of coal in the United States was made by Father Hennepin as occurring near Fort Creve Coeur on the Illinois River near the place where Peoria now stands. Anthracite was discovered in Rhode Island in 1760. Being graphitic in character it was not used, and even the excellent variety which occurs in Pennsylvania lay unutilized for forty years after its presence was known. All early use of coal was very local owing to lack of transportation, but with the advent of coal, transportation and the growth of cities became a possibility.

As society is now constituted, no mineral substance could be spared with greater difficulty, and, in fact, without coal modern civilization would be impossible. Railroads, steamships, and great manufacturing plants would disappear. Men would miserably perish in winter's cold or all be driven to the tropics.

TABLE OF VARIOUS COALS

Name	Physical Condition	Hardness	Gravity	Color	Remarks
Peat	Feltlike aggregates	1.5	1.05	Light brown	Heat value low. Found in swamps in northern countries.
Lignite	Earthy; slightly conchoidal fracture	1.5	1.2	Black; powder brown	Sooty flame; does not fuse nor coke in closed vessel; partly soluble in warm potassium hydrate yielding brown solution. In younger stratified rocks. Source of gasoline, benzine, petroleum, paraffine, carbolic acid, vinegar, etc. Chief fuel in portions of western United States.
Bituminous coal, classified as follows:	Compact; conchoidal fracture	2	1.4	Black; powder brown	Long yellow flame; some varieties fuse; others coke; soluble in potassium hydrate without leaving brown solution; vegetable structure shown after bleaching in nitric acid, potassium chlorate, and washing in alcohol. In older geological formations (Pennyslvanian). Underlying many hundred square miles of country in the United States. Chief fuel, source of gas, tar, oils, and other derivations.
1. Caking coal (fat)	Softens while burning				
2. Coking coal (lean)	Retains shape while burning				
3. Cherry coal	Bright, lustrous				
4. Splint coal	Slaty and heavy				
5. Pitch coal	Very black, coarse conchoidal fracture				
6. Glance coal	Satiny, brittle				
7. Cannel coal (candle)	Fine grained, bright flame, sufficiently tough to be used for boxes, buttons, chandeliers, etc.				
Anthracite	Compact; brittle; conchoidal fracture; absence of cleavage	2.5	1.7	Black to grayish	Difficult to ignite, burns with weak flame, does not fuse. Soluble in potassium hydrate without brown solution. Plant cells may be seen in ashes on microscopic slides. In limited areas in the oldest sedimentary rocks and crystalline schists.

One pound of coal in a good engine will produce six-horse-power for one hour. One ton will produce thirteen-thousand-horse-power; and since some railroads use ten thousand tons per day, they have the equivalent of the work of one hundred and thirty million horses for one hour—without the necessity of feeding the horses. It is estimated that one pound of coal can produce as many foot pounds of energy as one man in one day. Three hundred pounds will furnish as much power as one man per year. Then if half the coal produced in the United States in 1915 were used as a source of power, it could do the work of sixteen hundred million men. This furnishes one explanation of the remarkable growth in wealth of the United States in the last fifty years—a growth which has not been equaled before in the history of the world. In using coal so lavishly we are drawing on the energy stored in the earth by the slow growth and transformation of a succession of swamps and forests requiring the sunshine of millions of years. The disappearance of the coal supply is but a question of time. In less than 300 years workable coal seams will probably be exhausted in Europe. Those in other parts of the world will last longer. But coal producers and users should seek to avoid the wasteful methods which at present prevail in: (1) mining, (2) removal, and (3) in use in furnace, stove, and fireplace.

The following table shows the typical proportions of carbon, hydrogen, oxygen, and nitrogen in the transformation of wood to anthracite.

CHEMICAL CHANGES IN TRANSFORMATION OF WOOD TO COAL

	Carbon	Hydrogen	Oxygen and Nitrogen
Wood	50	6	43
Peat	59	6	33
Lignite	69	5.2	25
Bituminous coal	82	5	12.2
Anthracite coal	95	2.5	2.5

SUMMARY

Having proceeded thus far, the visitor to the museum has made the acquaintance of about 100 different minerals. Many more are worthy of his interest and attention; yet this number is sufficient to give an idea of the minerals which constitute the world, and which are used by man for ornament, for medicine, as the source of metal, for building material, and in many other ways.

Such a study furnishes results similar to those which would be obtained by a student of human society who went into a community of some 1,200 inhabitants and made the acquaintance of 100 different people engaged in different occupations, holding different responsibilities, and showing varied attainments. One who has finished such a study would have a fair idea of the whole community.

So one who has passed through the museum, noting carefully the minerals shown and giving attention to their physical and chemical laws, their geography, geology, and relation to human activities, has a good idea of the whole mineral world. It is not necessary for him to study all the thirteen hundred different species and varieties of minerals. However, for one who wishes to go farther, a comprehensive list of minerals is given on pages 202 to 275; and for further study he is referred to the books listed on page 200.

No country is better supplied with minerals than the United States, and few countries make as good use of their resources in this regard as we do. The world-war resulted in stimulating mineral production in this country. For a number of minerals we had been accustomed to go to foreign countries; for antimony we had gone to China, for chromium to New Caledonia, for graphite to Ceylon, for magnesite to Greece, for manganese and platinum to Russia, for sulphur to Sicily, for tin to Singapore, for vanadium to Peru. But with increased difficulty of ocean transportation, prospectors and producers became increasingly active in the search for and the mining of these minerals. So the time is near at hand when the United States may be nearly independent in regard to the minerals necessary for the activities of its people.

In 1915 the total wealth added to the country by our minerals was two billion three hundred and ninety-three million dollars.

New minerals and chemical substances are being constantly discovered, and with their discovery new ideas and inspiration is gained by advanced workers in various departments of science. Most prominent among recent advances are those which have been made by men studying the ultimate constitution of matter.

NAMES OF MINERALS

Among the minerals which we have seen, the name of one at least, kaolinite, is of Chinese origin; two are of Singhalese origin: corundum and tourmaline; three are of Arabic origin: marcasite, amber, and talc. Bismuth, zincite, and hornblende are taken directly from the German; while gold, silver, and iron are old Anglo-Saxon words.

Many minerals are named after some geographical locality, such as aragonite, anglesite, labradorite, muscovite, strontianite, tremolite.

Others are named after men distinguished in the science of mineralogy or otherwise—biotite, dolomite, goethite, franklinite, magnesite, magnetite, proustite, smithsonite, tennantite, witherite.

A still larger number were derived from the Latin language: sulphur, antimony, platinum, mercury, stibnite, argentite, erubesite, tetrahedrite, sylvite, fluorite, cassiterite, rutile, spinel, cerussite, mangenite, albite, enstatite, actinolite, garnet, celestite, asphalt.

And finally, a still larger number of mineral names originate from the Greek: diamond, graphite, copper, molybdenite, galena, chalcocite, sphalerite, cinnabar, pyrrhotite, chalcopyrite, pyrite, arsenopyrite, pyrargyite, halite, cryolite, chalcedony, cuprite, hematite, chromite, pyrolusite, limonite, calcite, siderite, rhodochrosite, malachite, azurite, orthoclase, microcline, oligoclase, anorthite, hypersthene, pyroxene, diopside, augite, rhodonite, barite, gypsum.

THE USES OF MINERALS

Minerals contribute toward the welfare of mankind in manifold ways. Many of the harder, more brightly colored, or highly refracting minerals since earliest times have been used as objects of personal adornment, and today among the most prized of all material objects are such minerals as diamonds, rubies, sapphires, emeralds, aquamarine, amethyst, agates, turquoise, tourmaline, olivene, rhodonite, and malachite.

The metals, together with their sulphides, oxides, carbonates, and silicates, play a weighty rôle in the life of men of all races and all stages of development. The condition of society would be materially different were there no gold, silver, platinum, copper, iron, tin, zinc, lead, paladium, chromium, aluminium, manganese, magnesium, mercury, antimony, or bismuth.

Some minerals form foods without which it would be well-nigh impossible for men to exist. For example, salt and the minerals which are the source of the alkalies are almost indispensable to life.

The number of minerals which are used in the arts and manufactures is large and important. Sulphur, phosporus, soda, potash, chlorine, fluorine, and calcium contribute largely to the wealth of men.

Attention has already been called to the indispensable character of the hydrocarbon compounds. Without them modern civilization would be an impossibility.

Minerals as rock constituents form mountains and plains, and by their decomposition furnish the ultimate food supply of mankind. The study of minerals in their capacity of soil-formers is one of surpassing interest.

HISTORY OF THE STUDY OF MINERALS

The science of mineralogy, depending as it does upon physics, chemistry, and other well-developed sciences, has been one of the latest to be pursued, although from very early times minerals were used for ornaments, weapons, and domestic utensils. While ancient literature abounds in references to minerals, little more was known about them in early times than their external form. Hebrew literature mentions the use of clay, niter, salt, sand, and sulphur, as well as of gold, silver, copper, emerald, agate, chalcedony, carnelian, jasper, onyx, sardonyx, topaz, ruby, and sapphire.

Aristotle, 322 B.C., who is reputed by his admirers "to have known something of every science," has given no evidence of acquaintance with minerals. Several references to the subject in his writings are thought to have been interpolations made later by other writers. Pliny, 79 A.D., was the first Latin writer to describe minerals, and his accounts are usually so incomplete as to leave doubt as to the minerals to which they apply! Avicenna (d. 1036), an Arabian doctor of medicine born near Bokhara, distinguished salts, metals, minerals, and stones. Agricola (d. 1555), a German doctor born in Joachims Thal, used the terms quartz and spar, and noted the hardness, cleavage, form, and luster of certain minerals. This is a short list to cover all the years to the seventeenth century. But during the latter part of the seventeenth century a number of men began to be interested in the subject, Robert Boyle (1691) investigating their chemistry, Niccolas Steno discovering the constancy of crystal angles, and Bartholinus noting the double refraction of calcite. During the eighteenth century Linnaeus, the great classifier, attempted to classify minerals according to their form, while Cronstedt attempted a chemical classification. Two Frenchmen, Romé de l'Isle and René Just Haüy, were enthusiastic investigators in crystallography. De l'Isle described and pictured many forms. Haüy discovered laws underlying them. Jealousy of each other's work made them enemies. Haüy enjoyed recording de l'Isle's errors while correcting them. But their work formed the basis of later work in crystallography.

During the nineteenth century the study of minerals was pursued by many workers and the advancement in many lines assumed admirable proportions. In Germany, Weiss developed the idea of systems of crystallization, Mohs investigated the natural history of minerals, and Werner studied chemical classification and developed determination of minerals by simple physical characteristics. In Germany, France, England, and America the number of workers increased, some pursuing the subject of crystal formation, as did Bravais, Sohncke, Naumann, Miller, and Liebisch; others working at the chemical side of the subject, as, for example, Berzelius, Rose, Bunsen, Mitscherlich, Plattner, and Rammelsberg; still others studying optical mineralogy, noting particularly the relation of form to physical properties—Brewster, Senarmont, Des Cloizeaux, Zirkel, Sorby, Wollaston. The systematic side of the subject was developed by Beudant, Breithaupt, Groth, and Dana. Fouqué, Michel Levy, and Daubrée gave attention to the artificial formation of minerals.

The increase in interest in the subject of mineral study has come largely from advance in mining and in the use of minerals in arts and manufactures. The study has been and is naturally one of materials rather than of laws; but as the science has progressed, the principles and laws have been gradually perceived and formulated. In the development of the science, contributions have been made to other sciences: to physics, knowledge of optical and electrical phenomena; to chemistry, knowledge of new substances; to geology, light on the origin, composition, and decay of rocks; to metallography, facts concerning the contents and treatment of ores. Within the last fifty years the number of workers in mineralogy has increased to such an extent that the list is an extensive one and the science has been brought to great perfection in various lines.

In the United States many excellent books on the subject have been written. No work has ever surpassed in completeness that of James Dwight Dana. His *System of Mineralogy*, which first appeared in 1837, has passed through six editions. After the elder Dana's death the *Manual of Mineralogy*, which first appeared in 1848 and has passed through thirteen editions, and the *Textbook of Mineralogy*, which first appeared in 1877, were rewritten, enlarged, and kept up to date, first by Edward Salisbury Dana and later by William E. Ford. Among many books which have appeared during the last dozen years, the following may be noted especially. In them there has been a general endeavor to present this rather difficult science in such a manner as to render it more attractive to the general student. Increasing use is made of diagrams, of models, and of photographs of minerals. Anyone wishing to pursue the subject further should consult the following excellent works:

Bayley, W. S., *Descriptive Mineralogy.* D. Appleton & Co., 1917.

Brush, G. J., and Penfield, S. L., *Determinative Mineralogy and Blowpipe Analysis.* John Wiley, 1907.

Butler, G. M., *Handbook of Minerals.* John Wiley, 1908.

Erni, H., and Brown, A. P., *Mineralogy Simplified.* Philadelphia, 1901.

Farrington, O. C., *Meteorites.* Lakeside Press, 1915.

———, *Gems and Gem Minerals.* Lakeside Press, 1902.

Fulton, A. E. H., *Crystallography and Practical Crystal Measurement.* Macmillan Co., 1911.

Gratacap, L. P., *Popular Guide to Minerals.* D. Van Nostrand Co., 1912.

Groth, P., and Jackson, B. H., *Optical Properties of Crystals.* John Wiley, 1910.

Iddings, J. P., *Rock Minerals.* John Wiley, 1906.

Johannsen, Albert, *Determination of Rock-Forming Minerals.* John Wiley, 1908.

Kraus, E. H., *Descriptive Mineralogy.* George Wahr, 1911.

Kunz, G. F., *Gems and Precious Stones of North America.* New York.

Lewis, J. V., *Determinative Mineralogy.* John Wiley, 1915.

Merrill, G. P., *Rocks, Rock Weathering, and Soils.* John Wiley, 1906.

———, *Non-Metallic Minerals.* Macmillan Co., 1904.

Moses, A. J., and Parsons, C. L., *Mineralogy, Crystallography, and Blowpipe Analysis.* D. Van Nostrand Co., 1909.

Phillips, A. H., *Mineralogy.* Macmillan Co., 1912.

Pirsson, L. V., *Rocks and Rock Minerals.* John Wiley, 1908.

Van Horn, F. R., *Lecture Notes on Mineralogy.* Cleveland: 1903.

Winchell, N. H. and A. N., *Elements of Optical Mineralogy.* D. Van Nostrand Co., 1909.

An attractive little monthly magazine, *The American Mineralogist,* edited by Edgar T. Wherry, to be obtained of H. W. Trudell, Philadelphia, describes new minerals and records events of interest to mineralogists. *Economic Geology, Mineral Industry, American Journal of Science, Science,* and other journals contain many articles on mineralogy. Various state geological reports and those of the United States Geological Survey are full of interesting and valuable information concerning occurrence and production of minerals.

COMPREHENSIVE LIST OF MINERALS

COMPREHENSIVE

	Composition	Form
I. ELEMENTS		
1. Diamond	C	Regular
2. Bort	C	Regular
3. Carbonado	C	Massive
4. Cliftonite	C	Massive
5. Graphite	C	Hexag.
6. Schungite	C	Amorph.
7. Sulphur	S	Ortho.
8. Selensulphur	SeS	Ortho.
9. Arsenic	As	Hexag.
10. Allemonite	$SbAs_3$	Hexag.
11. Tellurium	Te	Hexag.
12. Antimony	Sb	Hexag.
13. Bismuth	Bi	Hexag.
14. Zinc	Zn	Hexag.
15. Gold	Au	Regular
16. Electrum	Au·Ag	Regular
17. Silver	Ag	Regular
18. Copper	Cu	Regular
19. Mercury	Hg	Amorph.
20. Lead	Pb	Regular
21. Amalgam	(Ag,Hg)	Regular
22. Arquerite	$(Ag_{12}Hg)$	Regular
23. Kongsbergite	$(Ag_{32}Hg)$	Regular
24. Tin	Sn	Tetrag.
25. Platinum	Pt	Regular
26. Iridium	Ir	Regular
27. Iridosmine	IrOs	Hexag.
28. Nevyanskite	IrOs	Hexag.
29. Siserskite	IrOs	Hexag.
30. Palladium	Pd	Regular
31. Allopalladium	Pd	Hexag.
32. Iron	Fe	Regular
33. Awaruite	$FeNi_2$	Regular
34. Josephinite	Fe_2Ni_5	Regular
35. Meteoric Iron	Fe	Regular
36. Kamacite	$Fe_{14}Ni$	Regular
37. Taenite	Fe_nNi_n	Regular
38. Plessite	Fe_nNi_n	Regular
39. Cohenite	$(Fe,Ni,Co)_3C$	Regular
39*a*. Schreibersite	$(Fe,Ni,Co)_3P$	Tetrag.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
1.	Colorless	10	3.5	Kimberley	Gem
2.	Dark	10	3.5	Kimberley	Drills
3.	Black	10	3.5	Kimberley	
4.	Black	2.5	2.1	Meteorites	Carbon
5.	Black	1	2	Ceylon	Pencils
6.	Black	1	1.9	Russia	Carbon
7.	Yellow	2	2	Sicily	Drugs
8.	Reddish	.....	......	Sicily	Selenium
9.	Tin white	3.5	5.6	Freiberg	Drugs
10.	Tin white	3.5	6.2	Andreasberg	
11.	Tin white	2	6.1	Colorado	
12.	White	3	6.6	Japan	Alloys
13.	Reddish	2.5	9.8	Western U.S.	
14.	White	2	6.9	Australia	Zinc
15.	Yellow	2.5	19	Western U.S.	Coin
16.	Amber	2.5	15	Urals	Gold
17.	White	2.5	11	Western U.S.	Coin
18.	Red	2.5	8.9	Michigan	Wire
19.	White	.....	13.5	California	Amalgamation
20.	Gray	1.5	11.3	Colorado	Lead
21.	White	3	14	Sweden, S. America	Silver
22.	White	3	10	Sweden, S. America	
23.	White	3	14	Sweden, S. America	
24.	White	2	7	Siberia, N.S. Wales	Tin
25.	White	5	21	Urals	Dentistry
26.	Regular	6	22	Urals	Pen points
27.	White	6	21	Urals, S. America	Irdium and osmium
28.	White	6	19	Urals, S. America	
29.	White	6	21	Urals, S. America	
30.	Steel gray	4	11	Brazil	Palladium
31.	Steel gray	.....	......	Hartz	
32.	Iron black	4	7	Meteorites	Iron and nickel
33.	Gray	5	8	New Zealand	
34.	Gray	5	8	Oregon	
35.	Gray	4	7	Meteorites	
36.	Gray	4	7	Meteorites	
37.	Gray	4	7	Meteorites	
38.	Gray	4	7	Meteorites	
39.	Tin white	6	7	Meteorites	
39*a*.	Tin white	6	7	Meteorites	

COMPREHENSIVE

	Composition	Form
II. SULPHIDES		
1. *Sulphides of Semi-Metals*		
40. Realgar	AsS	Mono.
41. Orpiment	As_2S_3	Mono.
42. Stibnite	Sb_2S_3	Ortho.
43. Metastibnite	Sb_2S_3	Amorph.
44. Bismuthinite	Bi_2S_3	Ortho.
45. Guanajuatite	Bi_2Se_3	Ortho.
46. Tetradymite	$Bi_2(Te,S)_3$	Hexag.
47. Joseite	Bi,Te,Se	Hexag.
48. Wehrlite	Bi_3Te_2	Hexag.
49. Molybdenite	MoS_2	Hexag.
2. *Sulphides of Metals*		
a. Basic		
50. Dyscrasite	$Ag_3Sb \cdot Ag_6Sb$	Ortho.
51. Horsfordite	Cu_6Sb	Ortho.
52. Huntilite	Ag_3As	Ortho.
53. Animikite	Ag_9Sb	Ortho.
54. Domeykite	Cu_3As	Ortho.
55. Algodonite	Cu_6As	Ortho.
56. Whitneyite	Cu_9As	Ortho.
57. Chilenite	Ag_6Bi	Amorph.
58. Stützite	Ag_4Te	Hexag.
b. Monosulphides		
59. Galena	PbS	Regular
60. Cuproplumbite	$Cu_2S \cdot 2PbS$	Massive
61. Alisonite	$3Cu_2S \cdot PbS$	Massive
62. Altaite	AgTe	Regular
63. Clausthalite	PbSe	Regular
64. Tilkerodite	(PbCo)Se	Regular
65. Naumannite	$(Ag_2Pb)Se$	Regular
66. Argentite	Ag_2S	Regular
67. Jalpaite	$(Ag,Cu)_2S$	Regular
68. Hessite	Ag_2Te	Regular
69. Petzite	$(Ag,Au)_2Te$	Massive
70. Aguilarite	$Ag_2S \cdot Ag_2Se$	Regular
71. Berzelianite	Cu_2Se	Dend.
72. Lehrbachite	$PbSe \cdot HgSe$	Massive
73. Eucairite	$Cu_2Se \cdot Ag_2Se$	Regular
74. Zorgite	$(PbCu_2Ag_2)Se$	Massive
75. Crookesite	$(CuTlAg)_2Se$	Massive
76. Umangite	$CuSe \cdot Cu_2Se$	Massive
77. Chalcocite	Cu_2S	Ortho.
78. Stromeyerite	$(Ag,Cu)_2S$	Ortho.
79. Sternbergite	$AgFe_2S_3$	Ortho.
80. Frieseite	$Ag_2Fe_5S_8$	Ortho.
81. Acanthite	Ag_2S	Ortho.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
40.	Aurora red	1.5	3.5	California	Arsenic
41.	Yellow	1.5	3.5	Utah, Wyoming	
42.	Lead gray	2	5	Japan	Antimony
43.	Brick red	.....	......	Nevada	
44.	White, iridescent	2	6	England, N.C.	Bismuth
45.	Bluish gray	2	6	Mexico	
46.	Steel gray	1.5	7	North Carolina	
47.	Steel gray	2	7.9	Brazil	
48.	Steel gray	2	8.4	Hungary	
49.	Lead gray	1.5	4.6	Washington	Molybdenum
50.	Tin white	3.5	9.5	Hartz Mts.	Silver
51.	Tin white	.....	8.8	Mytilene	Copper
52.	Tin white	.....	7	Lake Superior	Silver
53.	White	.....	9	Lake Superior	
54.	Tin white	.....	7.5	Lake Superior	Copper
55.	Tin white	.....	7.6	Lake Superior	
56.	Reddish white	.....	8.4	Houghton, Mich.	
57.	Silver white	2	......	Chile	Silver
58.	Lead gray	.....	......	Nagyag	
59.	Lead gray	2.5	7	Missouri, Colorado	Lead
60.	Dark blue	.....	6	Chile	Copper
61.	Indigo blue	.....	6	Chile	
62.	Tin white	3	8.1	Chile, Colorado	Lead
63.	Lead gray	3	8	Hartz Mts.	Lead
64.	Lead gray	.....	8	Hartz Mts.	
65.	Iron black	2.5	8	Hartz Mts.	Silver
66.	Lead gray	2.5	7	Western U.S.	
67.	Lead gray	.....	6	Mexico	
68.	Lead gray	2.5	8	Boulder, Colo.	
69.	Iron black	2.5	9	California	Gold
70.	Iron black	2.5	7.5	Mexico	Silver
71.	Silver white	2	6.7	Sweden	Copper
72.	Iron black	.....	7.8	Hartz Mts.	Mercury
73.	Lead gray	.....	7.5	Chile	Copper
74.	Lead gray	2	7	Hartz Mts.	
75.	Lead gray	3	6.9	Sweden	Silver
76.	Cherry red	3	5.6	Argentina	Copper
77.	Lead gray	2	5	Montana	Copper
78.	Steel gray	2.5	6	Siberia, Colorado	Silver
79.	Pinchbeck brown	1	4.2	Saxony	
80.	Dark gray	2.5	4	Joachimsthal	
81.	Iron black	2.5	7	Joachimsthal	

COMPREHENSIVE

		Composition	Form
II.	SULPHIDES—*continued*		
82.	Sphalerite	ZnS	Regular
83.	Marmatite	ZnS·FeS	Regular
84.	Przibramite	ZnS·CdS	Regular
85.	Metacinnabarite	HgS	Regular
86.	Guadalcazarite	HgS·ZnS	Regular
87.	Tiemannite	HgSe	Regular
88.	Onofrite	Hg(S·Se)	Regular
89.	Coloradoite	HgTe	Regular
90.	Alabandite	MnS	Regular
91.	Oldhamite	CaS	Regular
92.	Pentlandite	(Fe,Ni)S	Regular
93.	Troilite	FeS	Hexag.
94.	Cinnabar	HgS	Hexag.
95.	Covellite	CuS	Hexag.
96.	Greenockite	CdS	Hexag.
97.	Wurtzite	ZnS	Hexag.
98.	Erythrozincite	ZnS·MnS	....
99.	Millerite	NiS	Hexag.
100.	Beyrichite	NiS	Hexag.
101.	Hauchecornite	$(Ni,Co)_7(S,Sb,Bi)_8$	Tetrag.
102.	Niccolite	NiAs	Hexag.
103.	Breithauptite	NiSb	Hexag.
104.	Pyrrhotite	$Fe_{11}S_{12}$	Hexag.
	c. Intermediate		
105.	Horbachite	$4Fe_2S_3Ni_2S_3$	Hexag.
106.	Polydymite	Ni_4S_5	Regular
107.	Grünauite	$Ni_4S_5 \cdot Bi_2S_3$	Regular
108.	Sychnodymite	$(Co,Cu)_4S_5$	Regular
109.	Melonite	Ni_2Te_3	Hexag.
110.	Bornite (=Erubesite)	$3Cu_2S \cdot Fe_2S_3$	Regular
111.	Linnaeite	$(Ni,Co,Fe)_3S_4$	Regular
112.	Daubreelite	$FeS \cdot Cr_2S_3$	....
113.	Cubanite	$CuFe_2S_4$	Regular
114.	Carrollite	$CuCo_2S_4$	Regular
115.	Chalcopyrite	$CuFeS_2$	Regular
	d. Disulphides		
116.	Pyrite	FeS_2	Regular
117.	Hauerite	MnS_2	Regular
118.	Smaltite-chloanthite	$CoAs_2 \cdot NiAs_2$	Regular
119.	Cobaltite	CoAsS	Regular
120.	Gersdorffite	NiAsS	Regular
121.	Corynite	Ni(As,Sb)S	Regular
122.	Willyamite	$CoS_2 \cdot NiS_2 \cdot CoSb_2 \cdot NiSb_2$	Regular
123.	Ullmannite	NiSbS	Regular
124.	Kallilite	Ni(Sb,Bi)S	Massive
125.	Sperrylite	$PtAs_2$	Regular
126.	Laurite	RuS_2	Regular

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
82.	Yellow	3.5	3.9	Missouri	Zinc
83.	Dark brown	.....	3.9	Cornwall	
84.	Dark brown	3.5	3.9	Hungary	
85.	Grayish black	3	7	California	Mercury
86.	....	2	7	Gaudalcazar, Mex.	
87.	Steel gray	2.5	8	Hartz Mts.	
88.	Blackish gray	2.5	8	Mexico	
89.	Iron black	3	8	Colorado	
90.	Iron black	3.5	3.9	Colorado	Manganese
91.	Pale brown	4	2.5	S.C. Meteorites	Calcium
92.	Bronze yellow	3.5	4.6	Norway	Nickel
93.	Tombac brown	4.7	4.7	Meteorites	Iron
94.	Reddish brown	2	8	Spain, California	Mercury
95.	Indigo blue	1.5	4.5	Chile	Copper
96.	Yellow	3.5	4.9	Scotland	Cadmium
97.	Brownish black	3.5	3.9	Peru	Zinc
98.	Red	2	3.9	Siberia	
99.	Brass yellow	3.5	5	Saxony	Nickel
100.	Lead gray	3	4.7	Westerwald	
101.	Bronze yellow	5	6	Westphalia	
102.	Copper red	5	7	Sweden	
103.	Red	5	7.5	Andreasberg	
104.	Bronze	3.5	4.5	Pennsylvania	Sulphur
105.	Steel gray	4.5	4	Horback	Nickel
106.	Gray	4.5	4.5	Grünau	
107.	Steel gray	4.5	5	Grünau	
108.	Steel gray	.....	4.7	Siegen	Cobalt
109.	Reddish white	.....	......	California	Nickel
110.	Copper	3	5	Chile	Copper
111.	Steel gray	5.5	4.8	Sweden	Cobalt
112.	Black	.....	5	Meteoric iron	Chromium
113.	Bronze	4	4	Cuba	Copper
114.	Steel gray	5.5	4.8	Maryland	
115.	Yellow	3.5	4	Western U.S.	Copper
116.	Yellow	6	5	Everywhere	Sulphur
117.	Brown	4	3	Hungary	Manganese
118.	Tin white	5.5	6	Saxony	Cobalt
119.	Silver white	5.5	6	Sweden	
120.	Silver white	5.5	6	Sweden	Nickel
121.	Silver white	4.5	5.9	Olsa	
122.	Silver white	5	7	New South Wales	Cobalt
123.	Steel gray	5.5	6	Germany	Nickel
124.	Bluish gray	.....	......	Germany	
125.	Tin white	6	10	Canada	Platinum
126.	Iron black	7.5	6.9	Borneo	Ruthenium

	Composition	Form
II. SULPHIDES—*continued*		
127. Skutterudite	$CoAs_3$	Regular
128. Nickel-skutterudite	$(Ni,Co,Fe)As_3$	Massive
129. Bismuto-smaltite	$Co(As,Bi)_3$	Massive
130. Marcasite	FeS_2	Ortho.
131. Löllingite	$FeAs_2$	Ortho.
132. Leucopyrite	Fe_3As_4	Ortho.
133. Geyerite	$Fe(AsS)_2$	Ortho.
134. Arsenopyrite	FeAsS	Ortho.
135. Danaite	FeCoAsS	Ortho.
136. Safflorite	$CoAs_2$	Ortho.
137. Rammelsbergite	$NiAs_2$	Ortho.
138. Glaucodot	(Co,Fe)AsS	Ortho.
139. Alloclasite	Co(As,Bi)S	Ortho.
140. Wolfachite	Ni(As·Sb)S	Ortho.
140*a*. Maucherite	Ni_3As_2	Tetrag.
e. Tellurides		
141. Sylvanite	$(Au,Ag)Te_2$	Mono.
142. Krennerite	$(Au,Ag)Te_2$	Ortho.
143. Calaverite	$(Au,Ag)Te_2$	Mono.
144. Nagyagite	$Au_2Pb_{14}Sb_3(S,Te)_{24}$	Ortho.
f. Oxysulphides		
145. Kermesite	Sb_2S_2O	Mono.
146. Voltzite	Zn_5S_4O	Globules

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
127.	Tin white	6	6.7	Norway	Cobalt
128.	Gray	.....	......	New Mexico	
129.	Tin white	.....	6.9	Zschorlau	
130.	Yellow	6.5	4.8	Bohemia	Sulphur
131.	Silver white	5.5	7	Lolling-Huttenberg	Arsenic
132.	Silver white	5.5	7	Lolling-Huttenberg	Arsenic
133.	....	.....	6.8	Saxony	
134.	Silver white	5.5	6	Freiberg	
135.	Gray	5.5	6	Franconia	Cobalt
136.	Tin white	4.5	7	Saxony	
137.	Tin white	5.5	7	Saxony	Nickel
138.	Tin white	5	5.9	Chile	Cobalt
139.	Steel gray	4.5	6.6	Orawitza	
140.	Silver white	4.5	6	Wolfach	Nickel
140½.	Reddish	5	7	Thuringen	
141.	Steel gray	1.5	7.9	Nagyag	Gold
142.	Silver white	.....	8	Nagyag, Colo.	
143.	Yellow	2.5	9	California, Colo.	
144.	Lead gray	1	6.8	Nagyag	
145.	Red	1	4.5	Hungary	Antimony
146.	Red	4	3.6	Joachimsthal	Zinc

	Composition	Form
III. SULPHO-SALTS		
1. *Sulpharsenites, etc.*		
a. Acidic		
147. Livingstonite	$HgS \cdot 2Sb_2S_3$	Ortho.
148. Chiviatite	$2PbS \cdot 3Bi_2S_3$	Ortho.
149. Cuprobismutite	$3Cu_2S \cdot 4Bi_2S_3$	Ortho.
150. Rezbanyite	$4PbS \cdot 5Bi_2S_3$	Ortho.
b. Meta		
151. Zinkenite	$PbSb_2S_4$	Ortho.
152. Andorite	$2(Pb,Ag,Sb)_3S_6$	Ortho.
153. Webnerite		
154. Sundtite		
155. Sartorite	$PbS \cdot As_2S_3$	Ortho.
156. Emplectite	$Cu_2S \cdot Bi_2S_3$	Ortho.
157. Chalcostibite	$Cu_2S \cdot Sb_2S_3$	Ortho.
158. Galenobismutite	$PbS \cdot Bi_2S_3$	Ortho.
159. Berthierite	$FeS \cdot Sb_2S_3$	Ortho.
160. Matildite	$Ag_2S \cdot Bi_2S_3$	Ortho.
161. Miargyrite	$Ag_2S \cdot Sb_2S_3$	Mono.
162. Lorandite	$TlAsS_2$	Mono.
c. Intermediate		
163. Plagionite	$5PbS \cdot 4Sb_2S_3$	Mono.
164. Schirmerite	$3(Ag_2,Pb)S \cdot 2Bi_2S_3$	Ortho.
165. Klaprotholite	$3Cu_2S \cdot 2Bi_2S_3$	Ortho.
166. Binnite	$3Cu_2S \cdot 2As_2S_3$	Regular
167. Warrenite	$3PbS \cdot 2Sb_2S_3$	Ortho.
168. Jamesonite	$Pb_2Sb_2S_5$	Ortho.
169. Dufrenoysite	$2PbS \cdot AS_2S_3$	Ortho.
170. Rathite	$2PbS \cdot As_2S_3$	Ortho.
171. Cosalite	$2PbS \cdot Bi_2S_3$	Ortho.
172. Kobellite	$2PbS \cdot (Bi,Sb)_2S_3$	Ortho.
173. Brongniardite	$PbS \cdot Ag_2S \cdot Sb_2S_3$	Regular
174. Semseyite	$7PbS \cdot 3Sb_2S_3$	Mono.
175. Schapbachite	$PbS \cdot Ag_2S \cdot Bi_2S_3$	Ortho.
176. Freieslebenite	$(Pb,Ag_2)_5 \cdot Sb_4S_{11}$	Mono.
177. Diaphorite	$(Pb,Ag_2)_5 \cdot Sb_4S_{11}$	Ortho.
180. Boulangerite	$Pb_3Sb_2S_6$	Ortho.
181. Embrithite	$10PbS \cdot 3Sb_2S_3$	Ortho.
d. Ortho		
182. Bournonite	$(Pb,Cu_2)_3Sb_2S_6$	Ortho.
183. Aikinite	$3(Pb,Cu_2)S \cdot Bi_2S_3$	Ortho.
184. Wittichenite	$3Cu_2S \cdot Bi_2S_3$	Ortho.
185. Stylotypite	$3(Cu_2,Ag_2,Fe)S \cdot Sb_2S_3$	Ortho.
186. Lillianite	$3PbS \cdot BiSbS_3$	Ortho.
187. Guitermanite	$3PbS \cdot As_2S_3$	Ortho.
188. Tapalpite	$3Ag_2(S,Te) \cdot Bi_2(S,Te)_3$	Ortho.
189. Pyrargyrite	Ag_3SbS_3	Hexag.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
147.	Lead gray	2	4.8	Mexico	Mercury
148.	Lead gray	.....	6.9	Chiviato	Lead
149.	Bluish black	.....	6	Colorado	Copper
150.	Lead gray	2.5	6	Hungary	Lead
151.	Steel gray	3	5	Hartz	Lead
152.	Dark gray	3	5	Felsobanya	Silver
153.					
154.					
155.	Dark gray	3	5	Binnenthal	Lead
156.	Tin white	2	6	Saxony	
157.	Gray	3	4.75	Hartz	
158.	Lead gray	3	6.9	Sweden	
159.	Steel gray	2	4	Saxony	Antimony
160.	Gray	2	6.9	Peru	Silver
161.	Iron black	2	5	Saxony	
162.	Red	2	5	Allchar	Thalium
163.	Lead gray	2.5	5	Wolfsberg	Lead
164.	Lead gray	2	6	Colorado	Silver
165.	Steel gray	2	4.6	Wittichen	Copper
166.	Steel gray	2.5	4	Tyrol	
167.	Grayish black	.....	......	Colorado	Lead
168.	Steel gray	2	5.5	Cornwall	
169.	Lead gray	3	5.5	Tyrol	
170.	Lead gray	3	5.5	Tyrol	
171.	Steel gray	2.5	6	Mexico	
172.	Steel gray	.....	6	Sweden, Colorado	
173.	Black	3.5	5.9	Mexico	Silver
174.	Gray	.....	5.9	Hungary	Lead
175.	Lead gray	3.5	6	Schapbach	Bismuth
176.	Steel gray	2	6	Frieberg	Silver
177.	Gray	2.5	5.9	Bohemia	
180.	Lead gray	2.5	5.7	France	Lead
181.	Lead gray	2.5	2.5	Nerchinsk	
182.	Gray	2.5	5.7	Hartz	Lead
183.	Lead gray	2	6	Urals	Bismuth
184.	Steel gray	3	4.5	Baden	
185.	Iron black	3	4.7	Chile	Antimony
186.	Steel gray	.....	......	Sweden	Lead
187.	Bluish gray	3	5.9	Colorado	
188.	Gray	3	7.8	Mexico	Bismuth
189.	Black	2.5	5.7	Andreasberg	Silver

COMPREHENSIVE

	Composition	Form
III. SULPHO-SALTS—*continued*		
190. Proustite	Ag_3AsS_3	Hexag.
191. Sanguinite	Ag_3AsS_3	Hexag.
192. Falkenhaynite	$3Cu_2S \cdot Sb_2S_3$	Regular
193. Pyrostilpnite	$3Ag_2S \cdot Sb_2S_3$	Mono.
194. Rittingerite	$Ag_{10}As_2Se_8$	Mono.
e. Basic		
195. Tetrahedrite	$Cu_8Sb_2S_7$	Regular
196. Freibergite	$Cu_8Sb_2S_7 \cdot Ag_2S$	Regular
197. Schwatzite	$Cu_8Sb_2S_7 \cdot HgS$	Regular
198. Tennantite	$Cu_8As_2S_7$	Regular
199. Jordanite	$4PbS \cdot As_2S_3$	Mono.
200. Menenghinite	$4PbS \cdot Sb_2S_3$	Ortho.
201. Stephanite	Ag_5SbS_4	Ortho.
202. Geocronite	$5PbS \cdot Sb_2S_3$	Ortho.
203. Beegerite	$6PbS \cdot Bi_2S_3$	Regular
204. Kilbrickenite	$6PbS \cdot Sb_2S_3$	Massive
205. Polybasite	Ag_9SbS_6	Mono.
206. Pearceite	$9Ag_2S \cdot As_2S_3$	Mono.
207. Polyargyrite	$12Ag_2S \cdot Sb_2S_3$	Regular
2. *Sulpharsenates, etc.*		
208. Enargite	Cu_3AsS_4	Ortho.
209. Clarite	Cu_3AsS_4	Mono.
210. Luzonite	Cu_3AsS_4	Massive
211. Famatinite	$3Cu_2S \cdot Sb_2S_5$	Ortho.
212. Xanthoconite	$3Ag_2S \cdot As_2S_5$	Hexag.
213. Epiboulangerite	$3PbS \cdot Sb_2S_5$	Ortho.
214. Epigenite	$4Cu_2S \cdot 3FeS \cdot As_2S_{56}$	Ortho.
215. Stannite	Cu_2FeSnS_4	Regular
216. Argyrodite	Ag_8GeS_6	Regular
217. Canfieldite	Ag_8SnS_6	Regular
218. Franckeite	$Pb_5Sb_2Sn_2S_{12}$	Massive
219. Cylindrite	$Pb_6Sb_2Sn_6S_{21}$	Massive
220. Sulvanite	$3Cu_2S \cdot V_2S_5$	Massive

LIST OF MINERALS

No.	Color	Hard-ness	Gravity	Locality	Chief Constituent or Use
190.	Scarlet	2	5.5	Freiberg	Silver
191.	Red	2	......	Chile	
192.	Gray black	.....	4.8	Joachimsthal	Copper
193.	Red	2	4	Andreasberg	Silver
194.	Iron black	2	5.6	Chile	
195.	Iron black	3	4	Hartz	Copper
196.	Steel gray	.....	4.8	Hartz	Silver and copper
197.	Iron black	.....	5	Hartz	Copper
198.	Iron black	3	4	Freiberg	
199.	Lead gray	3	6	Tyrol	Lead
200.	Lead gray	2.5	6	Tuscany	
201.	Iron black	2	6	Freiberg	Silver
202.	Lead gray	2.5	6	Sweden	Lead
203.	Gray	.....	6	Colorado	
204.	Lead gray	.....	6	Ireland	
205.	Iron black	2	6	Mexico	Silver
206.	Iron black	3	6	Colorado, Montana	
207.	Iron Black	2.5	6.9	Wolfach	
208.	Black	3	4	Peru	Copper
209.	Gray	3.5	4	Baden	
210.	Steel gray	3.5	4	Luzon	
211.	Gray	3.5	4.5	Argentina	
212.	Orange yellow	2	5	Freiberg	Silver
213.	Gray	.....	6	Altenberg	Lead
214.	Steel gray	3.5	......	Baden	Copper
215.	Steel gray	4	4	South Dakota	Tin
216.	Steel gray	2.5	6	Freiberg	Silver
217.	Black	.....	5.5	Bolivia	
218.	Blackish gray	.....	5.5	Bolivia	Lead
219.	Blackish gray	2.5	5	Bolivia	
220.	Bronze	3	4	Australia	Copper

		Composition	Form
	IV. HALOIDS		
	1. *Anhydrous*		
221.	Calomel	Hg_2Cl_2	Tetrag.
222.	Nantokite	Cu_2Cl_2	Regular
223.	Marshite	Cu_2I_2	Regular
224.	Halite	$NaCl$	Regular
225.	Huantajayite	$20NaCl \cdot AgCl$	Regular
226.	Sylvite	KCl	Regular
227.	Sal ammoniac	NH_4Cl	Regular
228.	Cerargyrite	$AgCl$	Regular
229.	Embolite	$Ag(Br,Cl)$	Regular
230.	Bromyrite	$AgBr$	Regular
231.	Iodobromite	$2AgCl \cdot 2AgBr \cdot AgI$	Regular
232.	Miersite	Ag_2I_2	Regular
233.	Cuproiodargyrite	$CuI \cdot AgI$	Incrust.
234.	Iodyrite	AgI	Hexag.
235.	Fluorite	CaF_2	Regular
235*a*.	Yttrofluorite	$(Ca_3,Y_2)F_6$	Regular
236.	Hydrophilite	$CaCl_2$	Regular
237.	Chloromagnosite	$MgCl_2$	Regular
238.	Scacchite	$MnCl_2$	Regular
239.	Chloralluminite	$AlCl_3 \cdot XH_2O$	Regular
240.	Molysite	$FeCl_3$	Incrust.
241.	Sellaite	MgF_2	Tetrag.
242.	Lawrencite	$FeCl_2$	Hexag.
243.	Cotunnite	$PbCl_2$	Ortho.
244.	Tysonite	$(Ce,La,Di)F_3$	Hexag.
245.	Cryolite	Na_3AlF_6	Mono.
246.	Chiolite	$5NaF \cdot 3AlF_3$	Tetrag.
247.	Hieratite	$2KF \cdot SiF_4$	Regular
	2. *Oxychlorides, etc.*		
248.	Atacamite	$Cu_2ClH_3O_3$	Ortho.
249.	Percylite	$PbCuO_2H_2Cl_2$	Regular
249*a*.	Boleite	$PbCuCl_2(OH)_2 \cdot \frac{1}{3}AgCl$	Regular
249*b*.	Cumengite	$PbCuCl_2(OH)_2 \cdot \frac{1}{3}AgCl$	Tetrag.
250.	Matlockite	Pb_2OCl_2	Tetrag.
251.	Mendipite	$Pb_2O_2Cl_2$	Ortho.
252.	Laurionite	$PbClOH$	Ortho.
253.	Fiedlerite	$PbClOH$	Mono.
254.	Penfieldite	Pb_3OCl_2	Hexag.
255.	Daviesite	$Pb \cdot O \cdot Cl$	Ortho.
256.	Schwartzembergite	$Pb(I,Cl)_2 2PbO$	Hexag.
257.	Fluocerite	$(Ce,La,Di)_2OF_4$	Hexag.
258.	Nocerite	$2(Ca,Mg)Fe \cdot (Ca,Mg)O$	Hexag.
259.	Daubreeite	$2Bi_2O_3 \cdot BiCl_3 \cdot 3H_2O$	Amorph.
	3. *Hydrous*		
260.	Carnallite	$KMgCl_3 6H_2O$	Ortho.
261.	Douglasite	$2KCl \cdot FeCl_2 2H_2O$	Mono.
262.	Bischofite	$MgCl_2 \cdot 6H_2O$	Mono.
263.	Kremersite	$KCl \cdot NH_4Cl_2 \cdot FeCl_2 \cdot H_2O$	Regular

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
221.	Gray	1	6	Spain	Medicine
222.	Colorless	2.5	3.9	Chile	Copper
223.	Oil brown	.....	......	New South Wales	
224.	Colorless	2.5	2	Kansas, Louisiana	Salt
225.	White	2	......	Chile	
226.	Colorless	2	1.9	Stassfurt	Potassium
227.	White	1.5	1.5	Vesuvius	Medicine
228.	Pearl gray	1	5.5	Colorado, Nevada	Silver
229.	Grayish green	1	5	Chile	
230.	Yellow	2	5.8	Mexico	
231.	Greenish	1.5	5.7	Nassau	
232.	Yellow	.....	......	New South Wales	
233.	Yellow	2	5.6	Peru	Iodine
234.	Yellow	1.5	5.6	New Mexico	
235.	Blue	4	3	Illinois	Flux
235½.	Yellow	4	3	Norway	Yttrium, fluorine
236.	White	.....	2.5	Vesuvius	Chlorine
237.	White	.....	......	Vesuvius	Magnesium
238.	White	.....	......	Vesuvius	Chlorine
239.	White	.....	......	Vesuvius	
240.	Red	.....	......	Vesuvius	
241.	Colorless	5	2.9	Savoy	Fluorine
242.	Green	.....	......	Meteorites	Iron
243.	White	.....	5	Vesuvius	Lead
244.	Wax yellow	4.5	6	Pike's Peak	Cerium
245.	Colorless	2.5	2.9	Western Greenland	Aluminum
246.	Snow white	3.5	2.8	Ilmen Mts.	
247.	Gray	.....	......	Vulcano	Potassium
248.	Green	3	3.7	Arizona	Copper
249.	Blue	2.5	......	Mexico	Lead and copper
249*a*.	Indigo blue	3	5	Lower California	
249*b*.	....	.....	......	....	
250.	Yellowish	2.5	7	Cromford	Lead
251.	White	2.5	7	England	
252.	Colorless	3	......	Greece	
253.	Colorless	.....	......	Greece	
254.	White	.....	......	Greece	
255.	Colorless	.....	......	Sierra Gorda	
256.	Honey yellow	2	6	Atacama	
257.	Yellow	4	5.7	Sweden	Cerium
258.	White	.....	......	Italy	Fluorine
259.	Yellow	2	6	Bolivia	Bismuth
260.	White	1	1.6	Stassfurt	Magnesium
261.	Colorless	.....	2	Stassfurt	Chlorine
262.	Colorless	1	1.6	Prussia	
263.	Red	.....	......	Vesuvius	

		Composition	Form
IV.	HALOIDS—*continued*		
264.	Erythrosiderite	$2KCl \cdot FeCl_3 \cdot H_2O$	Ortho.
265.	Tachhydrite	$CaCl_2 \cdot 2MgCl_2 \cdot 12H_2O$	Hexag.
266.	Fluellite	$AlF_3 \cdot H_2O$	Hexag.
267.	Prosopite	$CaF_2 \cdot 2Al(F,OH)_3$	Mono.
268.	Pachnolite	$NaF \cdot CaF_2 \cdot AlF_3 \cdot H_2O$	Mono.
269.	Thomsenelite	$NaCaAlF_6 \cdot H_2O$	Mono.
270.	Gearksutite	$CaF_2 \cdot Al(F,OH)_3 \cdot H_2O$	Earthy
271.	Ralstonite	$(Na_2Mg)F_2 \cdot 3Al(F,OH)_3 \cdot 2H_2O$	Regular
272.	Tallingite	$Cu_5(OH)_8Cl_2 \cdot 4H_2O$	Botry.
273.	Footeite	$8Cu(OH)_2 \cdot CuCl_2 \cdot 4H_2O$	Mono.
274.	Yttrocerite	$(Y,Er,Ce)F_3 \cdot 5CaF_6 \cdot H_2O$	Earthy

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
264.	Red	.....	......	Vesuvius	Chlorine
265.	Yellow	.....	......	Stassfurt	
266.	Colorless	3	2	Cornwall	Fluorine
267.	Colorless	4.5	2.8	Colorado	
268.	Colorless	3	2.9	Colorado	
269.	Colorless	2	2.9	Colorado	
270.	White	2	......	Colorado	
271.	Colorless	4.5	2.5	Greenland	
272.	Blue	3	3.5	Cornwall	Copper
273.	Blue	.....	......	Arizona	
274.	Blue	4	3	Sweden	Yttrium

	Composition	Form
V. OXIDES		
1. *Oxides of Silicon*		
275. Quartz	SiO_2	Hexag.
276. Star quartz	SiO_2	Hexag.
277. Amethyst	SiO_2	Hexag.
278. Rose quartz	SiO_2	Hexag.
279. Citrine	SiO_2	Hexag.
280. Cairngorm	SiO_2	Hexag.
281. Milky quartz	SiO_2	Hexag.
282. Sapphire quartz	SiO_2	Hexag.
283. Sagenitic	SiO_2	Hexag.
284. Cat's eye	SiO_2	Hexag.
285. Aventurine	SiO_2	Hexag.
286. Chalcedony	SiO_2	Crypto.
287. Carnelian	SiO_2	Crypto.
288. Chrysoprase	SiO_2	Crypto.
289. Prase	SiO_2	Crypto.
290. Plasma	SiO_2	Crypto.
291. Agate	SiO_2	Crypto.
292. Onyx	SiO_2	Crypto.
293. Sardonyx	SiO_2	Crypto.
294. Siliceous sinter	SiO_2	Crypto.
295. Flint	SiO_2	Crypto.
296. Hornstone	SiO_2	Crypto.
297. Basanite	SiO_2	Crypto.
298. Jasper	SiO_2	Crypto.
299. Quartzite	SiO_2	Crypto.
300. Itacolunite	SiO_2	Crypto.
301. Buhrstone	SiO_2	Crypto.
302. Silicified wood	SiO_2	Crypto.
303. Quartzine	SiO_2	Triclinic
304. Tridymite	SiO_2	Hexag.
305. Asmanite	SiO_2	Ortho.
306. Cristobalite	SiO_2	Regular
307. Melanophlogite	$SiO_2 \cdot O_3$	Regular
308. Opal	$SiO_2 \cdot H_2O$	Amorph.
309. Precious opal	$SiO_2 \cdot H_2O$	Amorph.
310. Fire opal	$SiO_2 \cdot H_2O$	Amorph.
311. Girasol	$SiO_2 \cdot H_2O$	Amorph.
312. Resin opal	$SiO_2 \cdot H_2O$	Amorph.
313. Hydrophane	$SiO_2 \cdot H_2O$	Amorph.
314. Milk opal	$SiO_2 \cdot H_2O$	Amorph.
315. Cacholong	$SiO_2 \cdot H_2O$	Amorph.
316. Opal agate	$SiO_2 \cdot H_2O$	Amorph.
317. Menilite	$SiO_2 \cdot H_2O$	Amorph.
318. Wood opal	$SiO_2 \cdot H_2O$	Amorph.
319. Hyalite	$SiO_2 \cdot H_2O$	Amorph.
320. Pearl sinter	$SiO_2 \cdot H_2O$	Amorph.
321. Geyserite	$SiO_2 \cdot H_2O$	Amorph.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
275.	Colorless	7	2.6	Ubiquitous	Abrasives
276.	Whitish	7	2.6	South America	Ornaments
277.	Purple	7	2.6	Colorado	
278.	Pink	7	2.6	Black Hills	
279.	Yellow	7	2.6	Colorado	
280.	Brown	7	2.6	Scotland	
281.	Milk white	7	2.6	Alleghanies	
282.	Indigo	7	2.6	Brazil	
283.	Colorless	7	2.6	Brazil	
284.	Milky	7	2.6	Ceylon	
285.	Red	7	2.6	Colorado	
286.	Various	7	2.6	Ubiquitous	Various
287.	Red.	7	2.6	Brazil	Gems
288.	Green	7	2.6	Colorado	Gems
289.	Leek green	7	2.6	Saxony	Ornaments
290.	Green	7	2.6	India	
291.	Banded	7	2.6	Colorado	
292.	Black and white	7	2.6	Colorado	
293.	Banded	7	2.6	Colorado	
294.	White	7	2.6	Yellowstone Park	Rock forming
295.	Brown	7	2.6	Chalk Cliffs	Arrow points
296.	Brown	7	2.6	Wyoming	Abrasives
297.	Black	7	2.6	California	
298.	Red	7	2.6	Colorado	Ornaments
299.	Various	7	2.6	Wisconsin	Rock forming
300.	Gray	7	2.6	North Carolina	Curios
301.	Gray	7	2.6	North Carolina	Millstones
302.	Various	7	2.6	Arizona	Ornaments
303.	Various	7	2.6	Colorado	
304.	Colorless	7	2	Yellowstone Park	
305.	Colorless	.....	......	Meteorites	
306.	White	6.5	2	Mexico	
307.	Brown	6.5	2	Sicily	
308.	Various	5.5	1.9	Hungary	Gems
309.	Various	5.5	1.9	Hungary	
310.	Red to yellow	5.5	......	Mexico	
311.	Bluish white	5.5	......	Mexico	
312.	Yellow	5.5	......	Mexico	
313.	White	5.5	1.9	Mountains	Gems
314.	Milk white	5.5	1.9	Mountains	
315.	White	5.5	1.9	Hungary	
316.	Light	5.5	1.9	Mountains	
317.	Amber	5.5	1.9	France	....
318	Dull grayish	5.5	1.9	Colorado	....
319.	Colorless	5.5	1.9	New Jersey, Conn.	....
320.	White	5.5	1.9	Yellowstone Park	....
321.	White	5.5	1.9	Yellowstone Park	....

	Composition	Form
V. OXIDES—*continued*		
322. Float stone	$SiO_2 \cdot H_2O$	Amorph.
323. Tripolite	$SiO_2 \cdot H_2O$	Amorph.
324. Infusorial earth	$SiO_2 \cdot H_2O$	Amorph.
2. *Semi-Metals*		
325. Arsenolite	As_2O_3	Regular
326. Claudetite	As_2O_3	Mono.
327. Senarmontite	Sb_2O_3	Regular
328. Valentinite	Sb_2O_3	Ortho.
329. Bismite	Bi_2O_3	Ortho.
330. Tellurite	TeO_2	Ortho.
331. Molybdite	MoO_3	Ortho.
332. Tungstite	WO_3	Ortho.
333. Cervantite	$Sb_2O_3 \cdot Sb_2O_5$	Ortho.
334. Stibiconite	$H_2Sb_2O_5$	Massive
3. *Metals*		
a. Protoxides		
335. Cuprite	Cu_2O	Hexag.
336. Chalcotrichite	Cu_2O	Hexag.
337. Tile ore	Cu_2O	Hexag.
338. Ice	H_2O	Hexag.
339. Periclase	MgO	Regular
340. Manganosite	MnO	Regular
341. Bunsenite	NiO	Regular
342. Zincite	ZnO	Hexag.
343. Massicot	PbO	Massive
344. Tenorite	CuO	Mono.
345. Paramelaconite	CuO	Tetrag.
b. Sesquioxides		
346. Corundum	Al_2O_3	Hexag.
347. Sapphire	Al_2O_3	Hexag.
348. Ruby	Al_2O_3	Hexag.
349. Emery	Al_2O_3	Hexag.
350. Hematite	Fe_2O_3	Hexag.
351. Specular hematite	Fe_2O_3	Hexag.
352. Columnar hematite	Fe_2O_3	Hexag.
353. Red ocherous hematite	Fe_2O_3	Hexag.
354. Clay ironstone	Fe_2O_3	Hexag.
355. Martite	Fe_2O_3	Regular
356. Ilmenite	$FeTiO_3$	Hexag.
357. Pyrophanite	$MnTiO_3$	Hexag.
c. Intermediate Oxides		
358. Spinel	$MgAl_2O_4$	Regular
359. Ruby spinel	$MgAl_2O_4$	Regular
360. Ceylonite-pleonaste	$(Mg,Fe)O \cdot Al_2O_3$	Regular

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
322.	White	5.5	1.9	Yellowstone Park	....
323.	White	5.5	1.9	Virginia	Abrasives
324.	Gray	5.5	1.9	Missouri	
325.	Colorless	.....	3.7	California	Drugs
326.	White	2.5	3.8	Portugal	Arsenic
327.	White	2	5.3	Quebec	Antimony
328.	White	2.5	5	New Brunswick	
329.	Straw yellow	.....	4.3	Cornwall	Bismuth
330.	White	2	5.9	Boulder, Colo.	Tellurium
331.	Straw yellow	1	4.5	Pennsylvania	Molybdenum
332.	Yellow	.....	......	North Carolina	Tungsten
333.	Yellow	4	4	Spain	Antimony
334.	Yellow	4	5	Arkansas	
335.	Red	3.5	5.8	W. United States	Copper
336.	Red	3.5	5.8	Arizona	
337.	Brown	3.5	5.8	Arizona	
338.	Colorless	1	0.9	Cold regions	Ice
339.	Grayish	6	3.6	Sweden	Magnesium
340.	Green	5	5	Sweden	Manganese
341.	Green	5	6	Johanngeorgenstadt	Nickel
342.	Red	4	5	New Jersey	Zinc
343.	Yellow	2	8	Mexico	Lead
344.	Black	3	5.8	Tennessee	Copper
345.	Black	5	5.8	Arizona	
346.	Various	9	4	Appalachians	Abrasives
347.	Blue	9	4	Ceylon	Gems
348.	Red	9	4	Upper Burma	
349.	Black	9	4	New York	Abrasives
350.	Red	6	5	New York	Iron
351.	Black	6	5	Elba	
352.	Brownish red	6	5	New York	
353.	Red	3	5.4	Minnesota	
354.	Brownish black	3	3	Minnesota	
355.	Iron black	6	4.8	East U.S.	Iron
356.	Iron black	5	4.5	East U.S.	
357.	Red	5	4.5	Sweden	Manganese
358.	Red	8	3.5	New York	Gems
359.	Red	8	3.6	New York	
360.	Brown	8	3.5	New York	

		Composition	Form
V.	Oxides—*continued*		
361.	Chlorospinel.........	$MgO \cdot (Al,Fe)_2O_3$	Regular
362.	Picotite-chrome spinel	$(Mg,Fe)O \cdot (Al,Fe,Cr)_2O_3$	Regular
363.	Hercynite...........	$FeAl_2O_4$	Regular
364.	Gahnite.............	$ZnAl_2O_4$	Regular
365.	Automolite..........	$ZnAl_2O_4$	Regular
366.	Dysluite............	$(Zn,Fe,Mn)O \cdot (Al,Fe)_2O_3$	Regular
367.	Kreittonite..........	$(ZnFe,Mg)O(Al,Fe)_2O_3$	Regular
368.	Magnetite..........	$FeO \cdot Fe_2O_3$	Regular
369.	Franklinite..........	$(Fe,Zn,Mn)O \cdot (Fe,Mn)_2O_3$	Regular
370.	Magnesioferrite......	$MgFeO_4$	Regular
371.	Jacobsite...........	$(Mn,Mg)O \cdot (Fe,Mn)_2O_3$	Regular
372.	Chromite...........	$FeO \cdot Cr_2O_3$	Regular
373.	Chrysoberyl.........	$BeAl_2O_4$	Hexag.
374.	Alexandrite.........	$BeAl_2O_4$	Hexag.
375.	Cat's eye...........	$BeAl_2O_4$	Hexag.
376.	Hausmannite........	Mn_3O_4	Tetrag.
377.	Minium............	Pb_3O_4	Powder.
378.	Crednerite..........	$Cu_3Mn_4O_9$	Mono.
379.	Pseudobrookite......	$Fe_4(TiO_4)_3$	Ortho.
380.	Braunite...........	$3Mn_2O_3 \cdot MnSiO_3$	Tetrag.
381.	Bixbyite...........	$FeO \cdot MnO_2$	Regular
	d. Dioxides		
382.	Cassiterite..........	SnO_2	Tetrag.
383.	Stream tin..........	SnO_2	Tetrag.
384.	Polianite...........	MnO_2	Tetrag.
385.	Rutile.............	TiO_2	Tetrag.
386.	Nigrine............	$TiO_2(+2\%Fe_2O_3)$	Tetrag.
387.	Ilmenorutile.........	$TiO_2(+10\%Fe_2O_3)$	Tetrag.
388.	Plattnerite..........	PbO_2	Tetrag.
389.	Baddeleyite.........	ZrO_2	Mono.
390.	Octahedrite.........	TiO_2	Tetrag.
391.	Brookite...........	TiO_2	Ortho.
392.	Pyrolusite..........	MnO_2	Amorph.
	e. Hydrous Oxides		
393.	Diaspore...........	$Al_2O_3 \cdot H_2O$	Ortho.
394.	Goethite...........	$Fe_2O_3 \cdot H_2O$	Ortho.
395.	Manganite..........	$Mn_2O_3 \cdot H_2O$	Ortho.
396.	Limonite...........	$2Fe_2O_3 \cdot 3H_2O$	Amorph.
397.	Bog ore............	$2Fe_2O_3 \cdot 3H_2O$	Amorph.
398.	Clay ironstone.......	$2Fe_2O_3 \cdot 3H_2O$	Amorph.
399.	Turgite............	$2Fe_2O_3 \cdot H_2O$	Amorph.
400.	Xanthosiderite......	$Fe_2O_3 \cdot 2H_2O$	Amorph.
401.	Bauxite............	$Al_2O_3 \cdot 2H_2O$	Grains
402.	Wocheinite..........	$Al_2O_3 \cdot 2H_2O$	Grains
403.	Brucite............	$MgO \cdot H_2O$	Hexag.
404.	Pyrochroite.........	$MnO \cdot H_2O$	Hexag.
405.	Gibbsite...........	$Al_2O_3 \cdot H_2O$	Mono.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
361.	Green	8	3.5	New York	Gems
362.	Brown	8	4	N.Y. and N.J.	
363.	Black	7.5	3.9	Ronsberg	Iron
364.	Green	7.5	4	New Jersey	Zinc
365.	Green	7.5	4	Sweden	
366.	Brown	7.5	4	Pennsylvania	
367.	Black	7	4	Brazil	
368.	Iron black	5.5	5	Adirondacks	Iron
369.	Black	6	5	New Jersey	Zinc
370.	Iron black	6	4.5	Vesuvius	Magnesium
371.	Black	6	4.7	Sweden	Manganese
372.	Black	5.5	4.5	W. United States	Chromium
373.	Green	8.5	3.5	Urals	Gems
374.	Green	8.5	3.6	Urals	
375.	Greenish	8.5	3.6	Ceylon	
376.	Black	5	4.8	Sweden	Manganese
377.	Red	2	4.6	Baden	Lead
378.	Iron black	4.5	4.9	Friedrichsrode	Manganese
379.	Dark brown	6	4	Transylvania	Titanium
380.	Dark brown	6	4.7	Hartz	Manganese
381.	Black	6	4.9	Utah	Iron
382.	Black	7	7	Malay Peninsula	Tin
383.	Black	7	7	Malay Peninsula	
384.	Steel gray	6	4.9	Bohemia	Manganese
385.	Red	6.5	4	Arkansas	Titanium
386.	Black	6.5	4	Arkansas	
387.	Black	.....	5	Ilmen Mts.	
388.	Iron black	5.5	8.5	Idaho	Lead
389.	Colorless	6.5	5.5	Ceylon	Zirconium
390.	Brown	5	3.8	Rhode Island	Titanium
391.	Brown	5.5	3.8	Arkansas	
392.	Black	2	4.7	Alabama	Manganese
393.	White	6.5	3	North Carolina	Aluminum
394.	Brown	5	4	Pa., Colorado	Iron
395.	Black	4	4	Colorado	Manganese
396.	Brown	5.5	3.8	Minnesota	Iron
397.	Brown	2	3.8	Minnesota	
398.	Brown	2	3.8	Widespread	
399.	Brown	2	4.1	Connecticut	
400.	Yellow	2.5	4.1	Hartz Mts.	
401.	Gray	3	2.5	Arkansas	Aluminum
402.	Gray	3	2.5	Carniola	
403.	White	2.5	2	New York	Magnesium
404.	White	2.5	3.2	New Jersey	Manganese
405.	White	2.5	2	New York	Aluminum

	Composition	Form
V. OXIDES—*continued*		
406. Sassolite............	$B_2O_3 \cdot 3H_2O$	Triclin.
407. Hydrotalcite........	$Al_2O_3 \cdot 6MgO \cdot 15H_2O$	Hexag.
408. Pyroaurite..........	$Fe_2O_3 \cdot 6MgO \cdot 15H_2O$	Hexag.
409. Chalcophanite.......	$(Mn,Zn)O \cdot 2MnO_2 \cdot 2H_2O$	Hexag.
410. Psilomelane.........	H_4MnO_5	Massive
411. Wad...............	$H_4MnO_5 \cdot H_2O$	Amorph.
412. Bog manganese......	$H_4MnO_5 \cdot H_2O$	Amorph.
413. Asbolite............	$H_4MnO_5 \cdot H_2O \cdot CoO$	Amorph.
414. Lampadite..........	$H_4MnO_5 \cdot H_2O \cdot (Co \cdot Cu)O$	Amorph.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
406.	White	1	1.4	California	Boric acid
407.	White	2	2	Norway	Magnesium
408.	White	.....	......	Sweden	
409.	Iron black	2.5	3.9	New Jersey	Manganese
410.	Iron black	5	4	Arkansas	
411.	Black	6	3	Germany	
412.	Black	6	3	Germany	
413.	Black	6	3	Germany	
414.	Black	.....	......	Germany	

COMPREHENSIVE

	Composition	Form
VI. CARBONATES		
1. *Anhydrous*		
415. Calcite	$CaCO_3$	Hexag.
416. Dog-tooth spar	$CaCO_3$	Hexag.
417. Nail-head spar	$CaCO_3$	Hexag.
418. Iceland spar	$CaCO_3$	Hexag.
419. Fontainebleau limestone	$CaCO_3$	Hexag.
420. Satin spar	$CaCO_3$	Hexag.
421. Argentine	$CaCO_3$	Lamellar
422. Aphrite	$CaCO_3$	Lamellar
423. Saccharoid. limestone.	$CaCO_3$	Crypto.
424. Shell marble	$CaCO_3$	Shelly
425. Lumachelle	$CaCO_3$	Chatoy.
426. Ruin marble	$CaCO_3$	Brecci.
427. Lithographic stone	$CaCO_3$	Massive
428. Hydraulic limestone	$CaCO_3$, also SiO_2,Al_2O_3, etc.	Massive
429. Chalk	$CaCO_3$	Massive
430. Oölite	$CaCO_3$	Granular
431. Pisolite	$CaCO_3$	Grains
432. Stalactite	$CaCO_3$	Cylind.
433. Stalagmite	$CaCO_3$	Cylind.
434. Calc sinter	$CaCO_3$	Incrust.
435. Travertine	$CaCO_3$	Incrust.
436. Agaric mineral	$CaCO_3$	Grains
437. Rock meal	$CaCO_3$	Grains
438. Thinolite	$CaCO_3$	Grains
439. Dolomite	$(Ca,Mg)CO_3$	Hexag.
440. Magnesite	$MgCO_3$	Hexag.
441. Breunnerite	$MgCO_3 \cdot H_2O$	Hexag.
442. Mesitite	$2MgCO_3 \cdot FeCO_3$	Hexag.
443. Pistomesite	$MgCO_3 \cdot FeCO_3$	Hexag.
445. Siderite	$FeCO_3$	Hexag.
446. Spherosiderite	$FeCO_3$	Concret.
447. Rhodochrosite	$MnCO_3$	Hexag.
448. Smithsonite	$ZnCO_3$	Hexag.
449. Sphaerocobaltite	$CoCO_3$	Hexag.
450. Aragonite	$CaCO_3$	Ortho.
451. Flos ferri	$CaCO_3$	Stalact.
452. Tarnowitzite	$CaCO_3 \cdot PbCO_3$	Stalcat.
453. Witherite	$BaCO_3$	Ortho.
454. Bromlite	$(Ba,Ca)CO_3$	Ortho.
455. Strontianite	$SrCO_3$	Ortho.
456. Cerussite	$PbCO_3$	Ortho.
457. Barytocalcite	$BaCO_3 \cdot CaCO_3$	Mono.
458. Bismutospharite	$Bi_2(CO_3)_3 \cdot 2Bi_2O_3$	Spherical
459. Parisite	$(CaF)(CeF)Ce(CO_3)_3$	Hexag.
460. Bastnäsite	$(Ce,La,Di)_2C_3O_9 \cdot (Ce,La,Di)F_3$	Hexag.
461. Phosgenite	$(PbCl)_2CO_3$	Tetrag.
462. Northupite	$MgCO_3 \cdot Na_2CO_3 \cdot NaCl$	Regular

LIST OF MINERALS

No	Color	Hardness	Gravity	Locality	Chief Constituent or Use
415.	Colorless	3	2.7	Ubiquitous	Calcium
416.	Colorless	3	2.7	Missouri	
417.	Colorless	3	2.7	Missouri.	
418.	Colorless	3	2.7	Iceland	Prisms
419.	Colorless	3	2.7	France	
420.	Colorless	3	2.7	France	Calcium
421.	White	3	2.7	France	
422.	White	3.5	2.7	France	
423.	Yellow	3	2.7	France	
424.	Yellow	3	2.7	Carinthia	
425.	Dark brown	3	2.7	France	
426.	Brown	3	2.7	Italy	
427.	Buff	3	2.7	Solenhofen	
428.	Buff	3	2.7	Virginia	
429.	White	3	2.7	England	
430.	White	3	2.7	Missouri	
431.	White	3	2.7	Missouri	
432.	White	3	2.7	Kentucky	
433.	White	3	2.7	Kentucky	
434.	White	3	2.7	Yellowstone Park	
435.	White	3	2.7	Tivoli	
436.	White	3	2.7	Caverns	
437.	White	3	2.7	Paris	
438.	Yellow	3	2.7	Nevada	
439.	White	3.5	2.8	Illinois	Building
440.	Colorless	4	3	Greece	Magnesium
441.	White	4	3	Massachusetts	
442.	Yellowish	3.5	3	Traversella	
443.	Yellowish	3.5	3	Traversella	
445.	Gray	3.5	3.8	Germany	Iron
446.	Brown	3.5	3.8	E. United States	
447.	Red	4	3	Colorado	Manganese
448.	White	5	4	Pennsylvania	Zinc
449.	Red	4	4	Saxony	Cobalt
450.	Colorless	3.5	2.9	New York, Illinois	Calcium
451.	White	3.5	2.9	New York, Illinois	
452.	White	.....	2.9	Silesia	
453.	Colorless	3.5	4.2	England	Barium
454.	White	4	3.7	England	
455.	Colorless	3.5	3.7	New York	Strontium
456.	Colorless	3.5	6	Cordilleras	Lead
457.	White	4	3.6	Cumberland	Barium
458.	Yellow	3	7	Saxony	Bismuth
459.	Yellow	4.5	4	Colombia	Cerium
460.	Yellow	4	4.9	Colorado	Lanthanum
461.	White	2.7	6	England	Lead
462.	White	.....	......	California	

		Composition	Form
VI.	CARBONATES—*continued*		
	2. *Hydrous*		
463.	Teschemacherite	HNH_4CO_3	Ortho.
464.	Malachite	$CuCO_3\cdot Cu(OH)_2$	Mono.
465.	Azurite	$2CuCO_3\cdot Cu(OH)_2$	Mono.
466.	Chessylite	$2CuCO_3\cdot Cu(OH)_2$	Mono.
467.	Aurichalcite	$2(Zn,Cu)CO_3\cdot 3(Zn,Cu)(OH)_2$	Mono.
468.	Hydrozincite	$ZnCO_3\cdot 2Zn(OH)_2$	Earthy
469.	Hydrocerussite	$2PbCO_3\cdot Pb(OH)_2$	Hexag.
470.	Dawsonite	$Na_3Al(CO_3)_3\cdot 2Al(OH)_3$	Mono.
471.	Thermonatrite	$Na_2CO_3\cdot H_2O$	Ortho.
472.	Nesquehonite	$MgCO_3\cdot 3H_2O$	Ortho.
473.	Natron	$Na_2CO_3\cdot 10H_2O$	Mono.
474.	Pirssonite	$CaCO_3\cdot Na_2CO_3\cdot 2H_2O$	Ortho.
475.	Gaylussite	$CaCO_3\cdot Na_2CO_3\cdot 5H_2O$	Mono.
476.	Lanthanite	$La_2(CO_3)_3\cdot 9H_2O$	Ortho.
477.	Trona	$Na_2CO_3\cdot HNaCO_3\cdot 2H_2O$	Mono.
478.	Hydromagnesite	$3MgCO_3\cdot Mg(OH)_2\cdot 3H_2O$	Amorph.
479.	Hydrogioberite	$MgCO_3\cdot Mg(OH)_2\cdot 2H_2O$	Compact
480.	Lansfordite	$3MgCO_3\cdot Mg(OH)_2\cdot 21H_2O$	Triclin.
481.	Zaratite	$NiCO_3\cdot 2Ni(OH)_2\cdot 4H_2O$	Stalact.
482.	Remingtonite	$CaCO_3\cdot H_2O$	Incrust.
483.	Tengerite	$YCO_3\cdot H_2O$	Pulver.
484.	Bismutite	$Bi_2O_3\cdot CO_2\cdot H_2O$	Amorph.
485.	Uranothallite	$2CaCO_3\cdot U(CO_3)_2\cdot 10H_2O$	Ortho.
486.	Liebigite	$CaCO_3\cdot (UO_2)CO_3\cdot 20H_2O$	Concret.
487.	Voglite	$(U,Ca,Cu)Co_3\cdot H_2O$	Scales

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
463.	Yellow	1.5	1.4	Africa	Lead
464.	Green	3.5	4	Arizona	Copper
465.	Blue	3.5	3.7	Arizona	
466.	Blue	3.5	3.7	France	
467.	Green	2	3.5	France	Zinc
468.	White	2	3.5	Pennsylvania	
469.	Colorless	2	6	Sweden	Lead
470.	White	3	2	Tuscany	Aluminum
471.	White	1	1.5	Nevada	
472.	Colorless	2.5	1.8	Pennsylvania	Magnesium
473.	Gray	1	1.4	Egypt	Sodium
474.	Colorless	3.5	2.3	California	
475.	White	2.3	1.9	Utah	
476.	White	2.5	2.6	Pennsylvania	Lanthanum
477.	Gray	2.5	2	Nevada	Sodium
478.	White	3.5	2	New Jersey	Magnesium
479.	Gray	.....	2	Italy	
480.	White	2.5	1.5	Pennsylvania	
481.	Green	3	2	Texas	Nickel
482.	Rose	2	......	Maryland	Cobalt
483.	White	.....	......	Texas	Ytterium
484.	White	4	6.8	South Carolina	Bismuth
485.	Green	2	......	Bohemia	Uranium
486.	Green	2	......	Joachimsthal	
487.	Green	.....	......	Joachimsthal	

COMPREHENSIVE

		Composition	Form
	VII. SILICATES		
	1. ***Anhydrous***		
	a. Disilicates		
488.	Petalite	$LiAl(Si_2O_5)_2$	Mono.
489.	Milarite	$HKCa_2Al_2(Si_2O_5)_6$	Hexag.
490.	Eudidymite	$HNaBeSi_3O_8$	Mono.
491.	Epididymite	$HNaBeSi_3O_8$	Ortho.
492.	Orthoclase	$KAlSi_3O_8$	Mono.
493.	Adularia	$KAlSi_3O_8$	Mono.
494.	Valencianite	$KAlSi_3O_8$	Mono.
495.	Sanidine	$KAlSi_3O_8$	Mono.
496.	Rhyacolite	$KAlSi_3O_8$	Mono.
497.	Loxoclase	$KAlSi_3O_8 \cdot 7Na_2O$	Mono.
498.	Murchisonite	$KAlSi_3O_8$	Mono.
499.	Perthite	$KAlSi_3O_8$	Mono.
500.	Hyalophane	$(K_2,Ba)Al_2(SiO_3)_4$	Mono.
501.	Microcline	$KAlSi_3O_8$	Triclinic
502.	Amazonstone	$KAlSi_3O_8$	Triclinic
503.	Chesterlite	$KAlSi_3O_8$	Triclinic
504.	Anorthoclase	$KAlSi_3O_8$	Triclinic
505.	Albite	$NaAlSi_3O_8$	Triclinic
506.	Peristerite	$NaAlSi_3O_8$	Triclinic
507.	Pericline	$NaAlSi_3O_8$	Triclinic
508.	Cleavelandite	$NaAlSi_3O_8$	Triclinic
509.	Oligoclase	*Ab_3An_1	Triclinic
510.	Sunstone	*Ab_3An_1	Triclinic
511.	Andesine	*Ab_3An_1	Triclinic
512.	Labradorite	*Ab_3An_1	Triclinic
513.	Maskelynite	*Ab_3An_1	Grains
514.	Anorthite	$CaAl_2Si_2O_8$	Triclinic
515.	Indianite	$CaAl_2Si_2O_8$	Triclinic
516.	Cyclopite	$CaAl_2Si_2O_8$	Triclinic
517.	Celsian	$BaAl_2Si_2O_8$	Triclinic
	b. Metasilicates		
518.	Leucite	$KAl(SiO_3)_2$	Ortho.
519.	Pollucite	$H_2Cs_4Al_4(SiO_3)9$	Regular
520.	Enstatite	$MgSiO_3$	Ortho.
521.	Chladnite	$MgSiO_3$	Ortho.
522.	Bronzite	$MgSiO_3$	Ortho.
523.	Hypersthene	$(Fe,Mg)SiO_3$	Ortho.
524.	Bastite	$(Fe,Mg)SiO_3$	Ortho.
525.	Peckhamite	$2(Mg,Fe)SiO_3 \cdot (Mg,Fe)SiO_4$	Ortho.
526.	Pyroxene	$Ca(Mg,Fe)Si_2O_6 \cdot (Mg,Fe)(AlFe)_2Si_2O_6$	Mono.
527.	Diopside	$CaMg(SiO_3)_2$	Mono.
528.	Malacolite	$CaMg(SiO_3)_2$	Mono.
529.	Alalite	$CaMg(SiO_3)_2$	Mono.
530.	Traversellite	$CaMg(SiO_3)_2$	Mono.
531.	Violan	$CaMg(SiO_3)_2$	Mono.

* Ab = Albite; An = Anorthite.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
488.	Colorless	6	2	Massachusetts	Lithium
489.	Colorless	5	2.5	Switzerland	Potassium
490.	White	6	2.5	Norway	Rock forming
491.	White	5.5	3.5	South Greenland	
492.	Colorless	6	2.5	California	
493.	Colorless	6	2.5	Switzerland	
494.	Colorless	6	2.5	Valencia	
495.	Colorless	6	2.5	Valencia	
496.	Colorless	6	2.5	Monte Somma	
497.	Colorless	6	2.5	New York	
498.	Red	6	2.5	England	
499.	Red	6	2.5	Ontario	
500.	Red	6	2.8	Sweden	
501.	White	6	2.5	Pike's Peak	
502.	White	6	2.5	Pike's Peak	
503.	White	6	2.5	Pennsylvania	
504.	White	6	2.5	Pennsylvania	
505.	White	6	2.6	E. United States	
506.	White	6	2.6	E. United States	
507.	White	6	2.6	E. United States	
508.	Bluish	6	2.6	New Hampshire	
509.	White	6	2.6	New York	
510.	White	6	2.6	Norway	
511.	White	5	2.6	Rocky Mts.	
512.	Gray	5	2.7	New York	
513.	Colorless	5	2.7	Meteorites	
514.	White	6	2.7	Mt. Vesuvius	
515.	White	6	2.7	India	
516.	White	6	2.7	Cyclopean Island	
517.	Colorless	6	3	Sweden	
518.	Colorless	5.5	2.5	Vesuvius	Rock forming
519.	White	6.5	2.9	Maine	
520.	Gray	5.5	3	New York	
521.	Gray	5.5	3	Meteorites	
522.	Green	5.5	3	New York	
523.	Brownish green	5	3	New York	
524.	Green	3.5	2.5	Hartz	
525.	Yellow	.....	3.2	Meteorites	
526.	White	5	3	Igneous rocks	
527.	Light green	5.5	3.3	Igneous rocks	
528.	Light green	5.5	3.3	Sweden	
529.	Green	5.5	3.3	Piedmont	
530.	Green	5.5	3.3	Traversella	
531.	Blue	5.5	3.3	Italy	

	Composition	Form
VII. SILICATES—*continued*		
532. Canaanite	$CaMg(SiO_3)_2$	Mono.
533. Lavrovite	$CaMg(SiO_3)_2$	Mono.
534. Hedenbergite	$CaFe(SiO_3)_2$	Mono.
535. Sahlite	$CaFe(SiO_3)_2$	Mono.
536. Baikalite	$CaFe(SiO_3)_2$	Mono.
537. Coccolite	$CaFe(SiO_3)_2$	Mono.
538. Diallage	$CaFe(SiO_3)_2$	Mono.
539. Omphacite	$CaFe(SiO_3)_2$	Mono.
540. Schefferite	$CaMg(Fe,Mn)(SiO_3)_2$	Mono.
541. Jeffersonite	Like schefferite+Zn	Mono.
542. Augite	$CaMg(SiO_3)_2$	Mono.
543. Leucaugite	$CaMg(SiO_3)_2$	Mono.
544. Fassaite	$CaMg(SiO_3)_2$	Mono.
545. Acmite	$NaFe(SiO_3)_2$	Mono.
546. Spodumene	$LiAl(SiO_3)_2$	Mono.
547. Hiddenite	$LiAl(SiO_3)_2$	Mono.
548. Jadeite	$NaAl(SiO_3)_2$	Mono.
549. Chloromelanite	$NaAl(SiO_3)_2$	Mono.
550. Nephrite	$NaAl(SiO_3)_2$	Mono.
551. Wollastonite	$CaSiO_3$	Mono.
552. Pectolite	$HNaCa_2(SiO_3)_3$	Mono.
553. Rosenbuschite	$6CaSiO_3 \cdot 2Na_2ZrO_2F_2 \cdot (TiSiO_3TiO_3)$	Mono.
554. Wöhlerite	$Ca_{10}Na_5Fe_3Nb_2Zr_3Si_{10}O_{42}$	Mono.
555. Låvenite	$(Na,Ca,Mn,Fe)(F,Zr,O)Si_2O_6$	Mono.
556. Rhodonite	$MnSiO_3$	Triclinic
557. Bustamite	Like rhodonite+Fe,Ca	Triclinic
558. Fowlerite	Like rhodonite+Fe,Ca,Zn	Triclinic
559. Babingtonite	$(Ca,Fe,Mn)SiO_3$	Triclinic
560. Hiortdahlite	$(Na_2,Ca)(Si,Zr)O_3$	Triclinic
561. Anthophyllite	$(Mg,Fe)SiO_3$	Ortho.
562. Gedrite	Like anthophyllite+Al	Ortho.
563. Amphibole	$CaMgFe[MnNa_2K_2H_2(SiO_3)_4]$	Mono.
564. Tremolite	$CaMg_3(SiO_3)_4$	Mono.
565. Actinolite	Like tremolite+Fe	Mono.
566. Nephrite	$CaMg_3(SiO_3)_4$	Compact
567. Asbestus, amianthus	$CaMg_3(SiO_3)_4$	Fibrous
568. Mountain leather	$CaMg_3(SiO_3)_4$	Fibrous
569. Mountain cork	$CaMg_3(SiO_3)_4$	Fibrous
570. Smaragdite	$CaMg_3(SiO_3)_4$	Fibrous
571. Uralite	$CaMg_3(SiO_3)_4$	Fibrous
572. Cummingtonite	Like actinolite+Mg	Fibrous
573. Dannemorite	Like actinolite+Mn	Fibrous
574. Grünerite	$FeSiO_3$	Fibrous
575. Richterite	$(K_2,Na_2,Mg,Ca,Mn,Fe)_4(SiO_3)_4$	Fibrous
576. Breislakite	$(K_2,Na_2,Mg,Ca,Mn)_4(SiO_3)_4$	Fibrous
577. Hornblende	$Ca(MgFe)_3SiO_3)_4 \cdot CaMg_2Al_2(SiO_4)_3$	Mono.
578. Edenite	$Ca(MgFe)_3SiO_3)_4 \cdot CaMg_2Al_2(SiO_4)_3$	Mono.
579. Koksharovite	$Ca(MgFe)_3SiO_3)_4 \cdot CaMg_2Al_2(SiO_4)_3$	Mono.
580. Pargasite	$Ca(MgFe)_3SiO_3)_4 \cdot CaMg_2Al_2(SiO_4)_3$	Mono.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
532.	Gray	5.5	3.3	Connecticut	Rock forming
533.	Green	5.5	3.3	East Siberia	
534.	Black	5.5	3.5	Sweden	
535.	Green	5.5	3.5	Sweden	
536.	Green	5.5	3.5	Siberia	
537.	Dark green	4	3	Mountains	
538.	Green	4	3	Mountains	
539.	Brown	4	3	Mountains	
540.	Brown	4	3	Mountains	
541.	Dark	6	3	New Jersey	
542.	Green	5.5	3.3	E. United States	
543.	White	6.5	3	E. United States	
544.	Green	6.5	3	Vesuvius	
545.	Gray	6	3.5	Colorado	
546.	Green	6.5	3	Massachusetts	
547.	Green	6.5	3	Massachusetts	
548.	Green	6.5	3	Asia	Ornaments
549.	Dark green	6.5	3	Asia	Rock forming
550.	Green	6.5	3	Asia	Ornaments
551.	White	4.5	2.8	New York	Rock forming
552.	White	5	2.6	New Jersey	
553.	White	5	2.6	Norway	
554.	Yellow	5.5	3.4	Norway	
555.	Yellow	6	3.5	Norway	
556.	Red	6	3.5	Russia	Ornaments
557.	Red	6	3.5	Mexico	
558.	Red	6	3.5	New Jersey	
559.	Black	5.5	3	Norway	
560.	Yellow	5.5	3	South Norway	
561.	Brown	5.5	3	North Carolina	Rock forming
562.	Brown	5.5	3	North Carolina	
563.	Green	5	2.9	Mountains	
564.	Gray	5	2.9	Mountains	
565.	Green	5	3	Mountains	
566.	Green	6	2.9	Mexico	Ornaments
567.	Gray	3	2.9	Mountains	Cloth
568.	Gray	3	2.9	Mountains	
569.	Gray	3	2.9	Mountains	
570.	Green	3	2.9	Alps	Rock forming
571.	Green	3	2.9	Alps	
572.	Gray	3	3	Massachusetts	
573.	Brown	3	3	Sweden	
574.	Brown	3	3.7	Sweden	
575.	Brown	3	3.7	Sweden	
576.	Brown	3	3.7	Vesuvius	
577.	Black	5.5	3	Vesuvius	
578.	Gray	5.5	3	New York	
579.	Gray	5.5	3	New York	
580.	Green	5.5	3	Finland	

		Composition	Form
VII.	SILICATES—*continued*		
581.	Kataforite	$Ca(MgFe)_3(SiO_3)_4 \cdot CaMg_2Al_2(SiO_4)_3$	Mono.
582.	Kupfferite	$Ca(MgFe)_3(SiO_3)_4 \cdot CaMg_2Al_2(SiO_4)_3$	Mono.
583.	Syntagmatite	$Ca(MgFe)_3(SiO_3)_4 \cdot CaMg_2Al_2(SiO_4)_3$	Mono.
584.	Bergamaskite	$Ca(MgFe)_3(SiO_3)_4 \cdot CaMg_2Al_2(SiO_4)_3$ (−Mg)	Mono.
585.	Kaersutite	Like amphibole+Ti	Mono.
586.	Hastingsite	Contains much Na	Mono.
587.	Glaucophane	$NaAl(SiO_3)_2 \cdot (Fe,Mg)SiO_3$	Mono.
588.	Gastaldite	$NaAl(SiO_3)_2 \cdot (Fe,Mg)SiO_3$	Mono.
588*a*.	Riebeckite	$2NaFe(SiO_3)_2 \cdot FeSiO_3$	Mono.
589.	Crocidolite	$NaFe(SiO_3)_2 \cdot FeSiO_3$	Mono.
590.	Abriachanite	$NaFe(SiO_3)_2 \cdot FeSiO_3$	Amor.
590*a*.	Arfvedsonite	$4Na_2O \cdot 3CaO \cdot 14FeO \cdot (Al,Fe)_2O_3 \cdot 21SiO_2$	Mono.
591.	Crossite	Like arfvedsonite+Na	Mono.
592.	Barkevikite	Like arfvedsonite+Na	....
593.	Aenigmatite	$Na_4Fe_9AlFe(SiTi)_{12}O_{38}$	Triclinic
594.	Beryl	$Be_3Al_2Si_6O_{18}$	Hexag.
595.	Emerald	$Be_3Al_2Si_6O_{18}$	Hexag.
596.	Aquamarine	$Be_3Al_2Si_6O_{18}$	Hexag.
597.	Davidsonite	$Be_3Al_2Si_6O_{18}$	Hexag.
598.	Eudialyte	$Na_{13}(Ca,Fe)_6Cl(Si,Zr)_{20}O_{52}$	Hexag.
599.	Eucolite	$Na_{13}(Ca,Fe)_6Cl(Si,Zr)_{20}O_{52}$	Hexag.
600.	Elpidite	$Na_2O \cdot ZrO_2 \cdot 6SiO_2 \cdot 3H_2O$	....
601.	Catapleiite	$H_4(Na_2,Ca)ZrSi_3O_{11}$	Hexag.
602.	Cappelenite	$3BaSiO_3 \cdot 2Y_2(SiO_3)_3 \cdot 5YBO_3$	Hexag.
603.	Melanocerite	$12(H_2Ca)SiO_3 \cdot 3(Y,Ce)BO_3 \cdot 2H_2(Th,Ce)O_2F_2 \cdot 8(Ce,La,Bi)OF$	Hexag.
604.	Caryocerite	$6(H_2,Ca)SiO_3 \cdot 2(Ce,Da,Y)BO_3 \cdot 3H_2(Ce,Th)O_2F_2 \cdot 2LaOF$	Hexag.
605.	Streenstrupine	Ti,Th,Ce,La,Di,Al,Fe,Mn,Ca,Na,H, silicate	Hexag.
606.	Tritomite	$2(H_2Na_2Ca)SiO_3 \cdot (Ce,La,Di,Y)BO_3 \cdot H_2(Ce,Th,Zr)O_2F$	Hexag.
607.	Leucophanite	$Na(BeF)Ca(SiO_3)_2$	Ortho.
608.	Meliphanite	$NaCa_2Be_2FSi_3O_{10}$	Tetrag.
609.	Iolite	$H_2(Mg,Fe)_4Al_8Si_{10}O_{37}$	Ortho.
610.	Bonsdorffite	$H_2(Mg,Fe)_4Al_8Si_{10}O_{37}$, altered	Ortho.
611.	Fahlunite	$H_2(Mg,Fe)_4Al_8Si_{10}O_{37}$, altered	Ortho.
612.	Pyrargillite	$H_2(Mg,Fe)_4Al_8Si_{16}O_{37}$, altered	Ortho.
613.	Esmarkite	$H_2(Mg,Fe)_4Al_8Si_{10}O_{37}$, altered	Ortho.
614.	Raumite	$H_2(Mg,Fe)_4Al_8Si_{10}O_{37}$, altered	Ortho.
615.	Chlorophyllite	$H_2(Mg,Fe)_4Al_8Si_{10}O_{37}$, altered	Ortho.
616.	Aspasiolite	$H_2(Mg,Fe)_4Al_8Si_{10}O_{37}$, altered	Ortho.
617.	Polychroilite	$H_2(Mg,Fe)_4Al_8Si_{10}O_{37}$, altered	Ortho.
618.	Barysilite	$Pb_3Si_2O_7$	....
619.	Ganomalite	$Pb_3Si_2O_7 \cdot (Ca,Mn)_2SiO_4$	Tetrag.
620.	Hyalotekite	$(Pb,Ba,Ca)_7B_2(SiO_3)_{12}$	....
621.	Barylite	$Ba_4Al_4Si_7O_{24}$	....
622.	Roeblingite	$5(H_2CaSiO_4) \cdot 2(CaPbSO_4)$	....
	c. Orthosilicates		
623.	Nephelite	$K_2Na_6Al_8Si_9O_{24}$	Hexag.
624.	Elaeolite	$K_2Na_6Al_8Si_9O_{24}$	Hexag.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
581.	Green	5.5	3	Norway	Rock forming
582.	Deep green	5.5	3	Tunkinsk Mts.	
583.	Black	5.5	3	Vesuvius	
584.	Black	5.5	3	Italy	
585.	Brown	5	3	North Greenland	
586.	Brown	5	3	Ontario	
587.	Blue	6	3	California	
588.	Blue	6	3	Corsica	
588*a*.	Black	6	3	Ireland	
589.	Blue	4	3	Rhode Island	
590.	Blue	4	3	Scotland	
590*a*.	Black	6	3	Colorado	
591.	Black	6	3	California	
592.	Black	6	3	Southern Norway	
593.	Black	.....	3	Southern Norway	
594.	Green	7.5	2.6	E. United States	Gems
595.	Green	7.5	2.6	E. United States	
596.	Green	7.5	2.6	E. United States	
597.	Green	7.5	2.6	Scotland	Rock forming
598.	Red	5	2.9	Western Greenland	
599.	Red	5	2.9	Norway	
600.	....	.....	2.5	South Greenland	
601.	Yellow	6	2.8	Norway	
602.	Brown	6	4.4	Norway	
603.	Brown	6	4	Norway	
604.	Brown	6	4	Norway	
605.	Brown	4	3	Greenland	
606.	Brown	5	4	Norway	
607.	Green	4	2.9	Norway	
608.	Yellow	5	3	Norway	
609.	Blue	7	2.6	Connecticut	
610.	Blue	7	2.6	Finland	
611.	Various	7	2.6	Sweden	
612.	Various	7	2.6	Helsingfors	
613.	Various	7	2.6	Norway	
614.	Various	7	2.6	Finland	
615.	Various	7	2.6	Maine	
616.	Various	7	2.6	Kragero	
617.	Various	7	2.6	Kragero	
618.	White	3	6	Sweden	
619.	Colorless	3	5.7	Sweden	
620.	White	5	3.8	Sweden	
621.	Colorless	7	4	Sweden	
622.	White	3	3	New Jersey	
623.	Colorless	5	2.5	Vesuvius	Rock forming
624.	Brown	5	2.5	Maine	

COMPREHENSIVE

		Composition	Form
VII.	SILICATES—*continued*		
625.	Gieseckite	$K_2Na_6Al_8Si_9O_{24} \cdot nH_2O$	Pseudo.
626.	Eucryptite	$LiAlSiO_4$	Hexag.
627.	Kaliophilite	$KAlSiO_4$	Hexag.
628.	Cancrinite	$H_6Na_6Ca(NaCO_3)_2Al_8(SiO_4)_9$	Hexag.
629.	Microsommite	$(Na,K)_{10}Ca_4Al_{12}Si_{12}O_{52}SCl_4$	Hexag.
630.	Sodalite	$Na_4(AlCl)Al_2(SiO_4)_3$	Regular
631.	Haüynite	$Na_2Ca_2(NaSO_4 \cdot Al)Al_2(SiO_4)_3$	Regular
632.	Noselite	$Na_4(NaSO_4 \cdot Al)Al_2(SiO_4)_3$	Regular
633.	Lazurite	$Na_4(NaS_3 \cdot Al)Al_2(SiO_4)_3$	Regular.
634.	Helvite	$(Mn,Fe)_2(Mn_2S)Be_3SiO_4)_3$	Regular
635.	Danalite	$(Fe,Zn,Mn)_2[(Zn,Fe)_2S]Be_3(SiO_4)_3$	Regular
636.	Eulytite	$Bi_4(SiO_4)_3$	Regular
637.	Zunyite	$(Al(OH,F,Cl)_2)_6Al_2(Si_6O_4)_3$	Regular
		II III	
638.	Garnet	$R_3R_2(SiO_4)_3$	Regular
639.	Grossularite	$Ca_3Al_2(SiO_4)_3$	Regular
640.	Cinnamon-stone	$Ca_3Al_2(SiO_4)_3$	Regular
641.	Hyacinth	$Ca_3Al_2(SiO_4)_3$	Regular
642.	Succinite	$Ca_3Al_2(SiO_4)_3$	Regular
643.	Romanzovite	$Ca_3Al_2(SiO_4)_3$	Regular
644.	Pyrope	$Mg_3Al_2(SiO_4)_3$	Regular
645.	Rhodolite	$Mg_3Al_2(SiO_4)_3$	Regular
646.	Almandite	$Fe_3Al_2(SiO_4)_3$	Regular
647.	Spessartite	$Mn_3Al_2(SiO_4)_3$	Regular
648.	Andradite	$Ca_3Fe_2(SiO_4)_3$	Regular
649.	Topazolite	$Ca_3Fe_2(SiO_4)_3$	Regular
650.	Demantoid	$Ca_3Fe_2(SiO_4)_3$	Regular
651.	Colophonite	$Ca_3Fe_2(SiO_4)_3$	Regular
652.	Melanite	$Ca_3Fe_2(SiO_4)_3$	Regular
653.	Pyreneite	$Ca_3Fe_2(SiO_4)_3$	Regular
654.	Rothoffite	$(CaMg)_3Fe_2(SiO_4)_3$	Regular
655.	Allochroite	$(Mg,Ca_3(Fe_2(SiO_4)_3$	Regular
656.	Polyadelphite	$(Mg,Ca)_3Fe_2(SiO_4)_3$	Regular
657.	Bredbergite	$(Mg,Ca)_3Fe_2(SiO_4)_3$	Regular
658.	Aplome	$(Mg,Ca)_3Fe_2(SiO_4)_3$	Regular
659.	Titaniferous garnet	$3CaO \cdot (Fe,Ti,Al)_2O_3 \cdot 3(Si,Ti)O_2$	Regular
660.	Yttergranat	$3CaO \cdot (Fe,Ti,Y,Al)YO_3$	Regular
661.	Uvarovite	$Ca_3Cr_2(SiO_4)_3$	Regular
662.	Schorlomite	$Ca_3(FeTi)_2(SiTi)O_4)_3$	Regular
663.	Partschinite	$(Mn,Fe)_3Al_2Si_3O_{12}$	Mono.
664.	Agricolite	$Bi_4Si_3O_{12}$	Mono.
665.	Chrysolite	$(Mg,Fe)_2SiO_4$	Ortho.
666.	Olivine	$(Mg,Fe)_2SiO_4$	Ortho.
667.	Hyalosiderite	$(Mg,Fe)_2SiO_4+Fe$	Ortho.
668.	Iddingsite	$(Ca,Mg,Fe)_2SiO_4$	Ortho.
669.	Monticellite	$CaMgSiO_4$	Ortho.
670.	Forsterite	Mg_2SiO_4	Ortho.
671.	Hortonolite	$(Fe,Mg,Mn)_2SiO_4$	Ortho.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
625.	Brown	5	2.6	New York	Rock forming
626.	Colorless	5	2.6	Connecticut	
627.	Colorless	6	2	Mt. Somma	
628.	Gray	5	2	Maine	
629.	Colorless	5	2	Vesuvius	
630.	Gray	5	2	Maine	
631.	Blue	5.5	2	Vesuvius	
632.	Grayish	5.5	2	Andernach	
633.	Blue	5	2	Chile	Ornaments
634.	Yellow	6	3	Virginia	Rock forming
635.	Red	5.5	3	Colorado	
636.	Brown	4.5	6	Saxony	
637.	Brown	7	2.8	Colorado	
638.	Red	6.5	3	Mountains	
639.	Pale green	6.5	3.5	Ceylon	
640.	Brown	6.5	3.5	Ceylon	
641.	Brown	6.5	3.5	Ceylon	
642.	Yellow	6.5	3.5	Piedmont	
643.	Brown	6.5	3.5	Russia	
644.	Red	6.5	3.7	Bohemia	
645.	Red	6.5	3.7	North Carolina	
646.	Red	6.5	3.9	Pennsylvania	
647.	Red	6.5	4	Colorado	
648.	Yellow	6.5	3.8	Portugal	
649.	Green	6.5	3.8	France	
650.	Green	6.5	3.8	Mountains	
651.	Brown	6.5	3.8	Mountains	
652.	Black	6.5	3.8	Mountains	
653.	Black	6.5	3.8	Mountains	
654.	Brown	6.5	3.8	Mountains	
655.	Brown	6.5	3.8	Mountains	Rock forming and gems
656.	Yellowish brown	6.5	3.8	New Jersey	
657.	Yellowish brown	6.5	3.7	Sala	
658.	Brown	6.5	3.7	Siberia	
659.	Black	6.5	3.7	Siberia	Rock forming
660.	Black	6.5	3.7	Norway	
661.	Green	7.5	3	Canada	
662.	Black	7	3.8	Arkansas	
663.	Yellow	6.5	4	Transylvania	
664.	Yellow	2	......	Johanngeorgen.	Bismuth
665.	Green	6.5	3	Virginia	Rock forming
666.	Green	6.5	3	Virginia	
667.	Green	6.5	3	Baden	
668.	Brown	.....	2.8	California	
669.	Gray	5	3	Arkansas	
670.	White	6	3	Vesuvius	
671.	Yellow	6	3.9	New York	

COMPREHENSIVE

	Composition	Form
VII. SILICATES—*continued*		
672. Fayalite	Fe_2SiO_4	Ortho.
673. Knebelite	$(Fe,Mn)_2SiO_4$	Ortho.
674. Tephroite	Mn_2SiO_4	Ortho.
675. Willemite	Zn_2SiO_4	Hexag.
676. Phenacite	Be_2SiO_4	Hexag.
677. Trimerite	$(Mn,Ca)_2SiO_4 \cdot Be_2SiO_4$	Triclinic.
678. Dioptase	H_2CuSiO_4	Hexag.
679. Friedelite	$H_7(MnCl)Mn_4Si_4O_{16}$	Hexag.
680. Pyrosmalite	$H_7([Fe,Mn\vert Cl)(Fe,Mn)_4Si_4O_{16}$	Hexag.
681. Meionite	$Ca_4Al_6Si_6O_{25}$	Tetrag.
682. Wernerite	*Me,Ma$_2$	Tetrag.
683. Passauite	*Me,Ma$_2$ or Ma$_3$	Tetrag.
684. Glaucolite	*Me,Ma$_2$ or Ma$_3$	Tetrag.
685. Mizzonite	Me,Ma$_3$	Tetrag.
686. Dipyre	Me,Ma$_3$	Tetrag.
687. Couseranite	Me,Ma$_3$	Tetrag.
688. Marialite	$Na_4Al_3Si_9O_{24}Cl$.	Tetrag.
689. Sarcolite	$Ca_8Na_2Al_6Si_9O_{36}$	Tetrag.
690. Melilite	$Na_2(Ca,Mg)_{11}(Al,Fe)_4(SiO_4)_9$	Tetrag.
691. Humboldtilite	$Na_2(Ca,Mg)_{11}(Al,Fe)_4(SiO_4)_9$	Tetrag.
692. Gehlenite	$Ca_3Al_2Si_2O_{10}$	Tetrag.
693. Vesuvianite	$H_4Ca_{12}(Al,Fe)_6S_{10}O_{43}$	Tetrag.
694. Cyprine	$H_4Ca_{12}(Al,Fe)_6S_{10}O_{43}$	Tetrag.
695. Zircon	$ZrSiO_4$	Tetrag.
696. Hyacinth	$ZrSiO_4$	Tetrag.
697. Jargon	$ZrSiO_4$	Tetrag.
698. Thorite	$ThSiO_4$	Tetrag.
699. Auerlite	$ThSiO_4$	Tetrag.
700. Danburite	$CaB_2(SiO_4)_2$	Ortho.
701. Topaz	$Al_2(F \cdot OH)_2SiO_4$	Ortho.
702. Physalite	$Al_2(F \cdot OH)_2SiO_4$	Ortho.
703. Pyonite	$Al_2(F \cdot OH)_2SiO_4$	Ortho.
704. Andalusite	Al_2SiO_5	Ortho.
705. Chiastolite	Al_2SiO_5	Ortho.
706. Sillimanite	Al_2SiO_5	Ortho.
707. Cyanite	Al_2SiO_5	Triclinic
708. Datolite	$HCaBSiO_5$	Mono.
709. Homilite	$(Ca,Fe)_3B_2Si_2O_{10}$	Mono.
710. Euclase	$HBeAlSiO_5$	Mono.
711. Gadolinite	$Be_2FeY_2Si_2O_{10}$	Mono.
712. Yttrialite	$(ThY)_2O_3 \cdot 2SiO_2$	Amorph.
713. Rowlandite	Y,Fe,U,Ca, silicate	Massive
714. Mackintoshite	T,Ce,U, silicate	Massive
715. Zoisite	$HCa_2Al_3Si_3O_{13}$	Ortho.
716. Thulite	$HCa_2Al_3Si_3O_{13}$	Ortho.
717. Epidote	$HCa_2(Al,Fe)_3Si_3O_{13}$	Mono.
718. Scorza	$HCa_2(Al,Fe)_3Si_3O_{13}$	Sand
719. Thallite	$HCa_2(Al,Fe)_3Si_3O_{13}$	Mono.

---

*Me = Meionite; Ma = Marialite.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
672.	Brown	6	4	Yellowstone Park	Rock forming
673.	Brown	6	4	Sweden	
674.	Red	5.5	4	New Jersey	
675.	White	5.5	3.8	New Jersey	Zinc
676.	Colorless	7.5	2.9	Colorado	Gems
677.	Pink	6	3	Sweden	Rock forming
678.	Green	5	3	Arizona	
679.	Red	4	3	Pyrenees	
680.	Gray	4	3	Sweden	
681.	Colorless	5.5	2.7	Vesuvius	
682.	White	5	2.6	Finland	
683.	Yellowish	5	2.6	Bavaria	
684.	Gray	5	2.6	Siberia	
685.	White	5	2.6	Vesuvius	
686.	White	5	2.6	Norway	
687.	White	5	2.6	Pyrenees	
688.	White	5	2.6	Naples	
689.	Red	6	2.5	Vesuvius	
690.	White	5	2.9	Vesuvius	
691.	Yellow	5	2.9	Vesuvius	
692.	Green	5	2.9	Tyrol	
693.	Brown	6.5	3	California	
694.	Blue	6.5	3	Norway	
695.	Yellow	7.5	4.6	New York	
696.	Red	7.5	4.6	Canada	
697.	Smoky	7.5	4.6	Ceylon	
698.	Black	4.5	5	Norway	
699.	Orange	2.5	4	North Carolina	
700.	Yellow	7	2.9	Connecticut	
701.	Yellow	8	3	Urals	Gems
702.	Yellow	8	3	Finbo	Rock forming
703.	Yellow	8	3	Saxony	
704.	Red	7.5	3	E. United States	
705.	Brown	7	3	Maine	
706.	Brown	6	3	E. United States	
707.	Blue	5	3.5	E. United States	
708.	White	5	2.9	New Jersey	
709.	Black	5	3	Norway	
710.	Colorless	7.5	3	Brazil	
711.	Black	6.5	4	Texas	
712.	Green	5	4.5	Texas	
713.	Drab green	.....	4.5	Texas	
714.	Black	.....	......	Texas	
715.	Gray	6	3	Carinthia	
716.	Red	6	3	Carinthia	
717.	Green	6	3	Michigan	
718.	Green	6	3	Transylvania	
719.	Yellow	6	3	Bourg d'Oisans	

COMPREHENSIVE

		Composition	Form
VII.	SILICATES—*continued*		
720.	Bucklandite	$HCa_2(Al,Fe)_3Si_3O_{13}$	Mono.
721.	Withamite	$HCa_2(Al,Fe)_3Si_3O_{13}$	Mono.
722.	Clinozoisite	$HCa_2(Al,Fe,Mn)_3Si_3O_{13}$	Mono.
723.	Picroepidote	$HCa_2(Al,Fe,Mn)_3Si_3O_{13}$	Mono.
724.	Piedmonite	$HCa_2(Al,Fe,Mn)_3Si_3O_{13}$	Mono.
725.	Allanite	Al,Fe,Mn,Ca,Na,K,Mg,Er,Y,La,Di,Ce, Th, silicate	Mono.
726.	Bagrationite	Al,Fe,Mn,Ca,Na,K,Mg,Er,Y,La,Di,Ce, Th, silicate	Mono.
727.	Axinite	$H_2(Ca,Mn)_4(BO)Al_3(SiO_4)_5$	Triclinic
728.	Prehnite	$H_2Ca_2Al_2(SiO_4)_3$	Ortho.
729.	Harstigite	$H_7(Ca,Mn)_{12}Al_3Si_{10}O_{40}$	Ortho.
730.	Cuspidine	$Ca_2Si(O,F_2)_4$	Mono.
	d. Subsilicates		
731.	Chondrodite	$H_2(Mg,Fe)_{19}Si_8O_{34}F_4$	Mono.
732.	Humite	$H_2(Mg,Fe)_{19}Si_8O_{34}F_4$	Ortho.
733.	Clinohumite	$H_2(Mg,Fe)_{19}Si_8O_{34}F_4$	Mono.
734.	Ilvaite	$CaFe_2(FeOH)(SiO_4)_2$	Ortho.
735.	Ardennite	$H_5Mn_4Al_4VSi_4O_{23}$	Ortho.
736.	Längbanite	$37Mn_5SiO_7 \cdot 10Fe_3Sb_2O_8$	Hexag.
737.	Kentrolite	$Pb_2Mn_2Si_2O_9$	Ortho.
738.	Melanotekite	$Pb_2Fe_2Si_2O_9$	Ortho.
739.	Bertrandite	$H_2Be_4Si_2O_9$	Ortho.
740.	Calamine	$H_2Zn_2SiO_5$	Ortho.
741.	Clinohedrite	$H_2CaZnSiO_5$	Mono.
742.	Carpholite	$H_4MnAl_2Si_2O_{10}$	Mono.
743.	Lawsonite	$H_4CaAl_2Si_2O_{10}$	Ortho.
744.	Cerite	$Ce_2(OH)_3CeO \cdot CaFe(SiO_3)_3$	Ortho.
745.	Tourmaline	$Fe_4Na_2B_6Al_{14}H_8Si_{12}O_{63}$	Hexag.
746.	Indicolite	$Fe_4Na_2B_6Al_{14}H_8Si_{12}O_{63}$	Hexag.
747.	Aphrizite	$Fe_4Na_2B_6Al_{14}H_8Si_{12}O_{63}$	Hexag.
748.	Achroite	$(Fe_4Na_2B_6Al_{14}H_8Si_{12}O_{63})$, etc.	Hexag.
749.	Dumortierite	$4Al_2O_3 \cdot 3SiO_2$	Ortho.
750.	Staurolite	$HFeAl_5Si_2O_{13}$	Ortho.
751.	Nordmarkite	$HFeAl_5Si_2O_{13}+Mg$	Ortho.
752.	Kornerupine	$MgAl_2SiO_6$	Ortho.
753.	Sapphirine	$Mg_5Al_{12}Si_2O_{27}$	Mono.
	2. *Hydrous*		
	a. Zeolites		
754.	Inesite	$2(Mn,Ca)SiO_3 \cdot H_2O$	Triclinic
755.	Ganophyllite	$Mn_7Al_2Si_8O_{26} \cdot 6H_2O$	Mono.
756.	Okenite	$H_2CaSi_2O_6 \cdot H_2O$	Ortho.
757.	Gyrolite	$H_2Ca_2(SiO_3)_3 \cdot H_2O$	Ortho.
758.	Apophyllite	$H_7KCa_4(SiO_3)_8 \cdot 4\frac{1}{2}H_2O$	Tetrag.
759.	Ptilolite	$(CaK_2Na_2)Al_2SiO_{24} \cdot 5H_2O$	Mono.
760.	Mordenite	$(CaK_2Na_2)Al_2Si_{10}O_{24} \cdot 6H_2O$	Mono.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
720.	Black	6	3	Bourg d'Oisans	Rock forming
721.	Red	6	3	Scotland	
722.	Rose red	.....	......	Ceylon	
723.	Yellowish	6	3	Siberia	
724.	Brown	6.5	3	Pennsylvania	
725.	Brown	5.5	3	Massachusetts	
726.	Black	6	3.8	Massachusetts	
727.	Brown	6.5	3	Maine	
728.	Green	6	2.8	Connecticut	
729.	Colorless	5.5	3	Sweden	
730.	Red	5	2.8	Mt. Somma	
731.	Yellow	6	3	Mt. Somma	Rock forming
732.	Yellow	6	3	New York	
733.	Yellow	6	3	New York	
734.	Iron black	5.5	3.9	Elba	
735.	Yellow	6.7	3.6	Belgium	
736.	Black	6.5	4.9	Sweden	
737.	Brown	5	6	Chile	
738.	Black	6.5	5.7	New Mexico	
739.	Colorless	6	2.5	Colorado	
740.	White	4.5	3	New Jersey	Zinc
741.	Colorless	5.5	3	New Jersey	Rock forming and gems
742.	Yellow	5	2.9	Hartz	
743.	Colorless	.....	3	California	
744.	Gray	5.5	4.8	Sweden	
745.	Black	7	2.9	Maine	
746.	Blue	7	2.9	Maine	
747.	Black	7	2.9	Norway	
748.	Colorless	7	2.9	Elba	
749.	Blue	7	3	Arizona	
750.	Brown	7	3.6	New Hampshire	
751.	Brown	7	3.6	Sweden	
752.	Colorless	6.5	3	Greenland	
753.	Green	7.5	3	Greenland	
754.	Red	6	3	Germany	Rock forming
755.	Brown	4	2.8	Sweden	
756.	White	4.5	2	Iceland	
757.	White	.....	......	California	
758.	White	4.5	2	New Jersey	
759.	Colorless	.....	......	Colorado	
760.	White	3	2	Wyoming	

		Composition	Form
VII.	SILICATES—*continued*		
761.	Heulandite	$H_4CaAl_2(SiO_3)_6 \cdot 3H_2O$	Mono.
762.	Brewsterite	$H_4(Sr,Ba,Ca)Al_2Si_6O_{18} \cdot 3H_2O$	Mono.
763.	Epistilbite	$H_4CaAl_2Si_6O_{18} \cdot 3H_2O$	Mono.
764.	Wellsite	$(Ba,CaK_2)Al_2Si_3O_{10} \cdot 3H_2O$	Mono.
765.	Phillipsite	$(K_2,Ca)Al_2Si_4O_{12} \cdot 4\frac{1}{2}H_2O$	Mono.
766.	Harmotome	$H_2(K_2,Ba)Al_2Si_5O_{15} \cdot 4H_2O$	Mono.
767.	Stilbite	$H_4(Na_2,Ca)Al_2Si_6O_{18} \cdot 4H_2O$	Mono.
768.	Gismondite	$CaAl_2Si_4O_{12} \cdot 4H_2O$	Mono.
769.	Laumontite	$H_4CaAl_2Si_4O_{14} \cdot 2H_2O$	Mono.
770.	Leonhardite	$H_4CaAl_2Si_4O_{14} \cdot 2H_2O$	Mono.
771.	Schneiderite	$H_4CaAl_2Si_4O_{14} \cdot 2H_2O$	Mono.
772.	Laubanite	$Ca_2Al_2Si_5O_{15}+6H_2O$	Mono.
773.	Chabazite	$(Ca,Na_2)Al_2Si_4O_{12} \cdot 6H_2O$	Hexag.
774.	Acadialite	$(Ca,Na_2)Al_2Si_4O_{12} \cdot 6H_2O$	Hexag.
775.	Haydenite	$(Ca,Na_2)Al_2Si_4O_{12} \cdot 6H_2O$	Hexag.
776.	Phacolite	$(Ca,Na_2)Al_2Si_4O_{12} \cdot 6H_2O$	Hexag.
777.	Herschelite	$(Ca,Na_2)Al_2Si_4O_{12} \cdot 6H_2O$	Hexag.
778.	Gmelinite	$(Na_2,Ca)Al_2Si_4O_{12} \cdot 6H_2O$	Hexag.
779.	Levynite	$CaAl_2Si_3O_{10} \cdot 5H_2O$	Hexag.
780.	Offretite	$(K_2Ca)_2Al_3Si_{14}O_{39} \cdot 17H_2O$	Hexag.
781.	Analcite	$NaAlSi_2O_6 \cdot H_2O$	Regular
782.	Analcime	$NaAlSi_2O_6 \cdot H_2O$	Regular
783.	Edingtonite	$BaAl_2Si_3O_{10} \cdot 3H_2O$	Tetrag.
784.	Natrolite	$Na_2Al_2Si_3O_{10} \cdot 2H_2O$	Ortho.
785.	Bergmannite	$Na_2Al_2Si_3O_{10} \cdot 2H_2O$	Ortho.
786.	Scolecite	$CaAl_2Si_3O_{10} \cdot 3H_2O$	Mono.
787.	Mesolite	$CaAl_2Si_3O_{10} \cdot 3H_2O+Na_2Al_2Si_3O_{10} \cdot 2H_2O$	Mono.
788.	Thomsonite	$(Na_2,Ca)Al_2Si_2O_8 \cdot 2\frac{1}{2}H_2O$	Ortho.
789.	Ozarkite	$(Na_2,Ca)Al_2Si_2O_8 \cdot 2\frac{1}{2}H_2O$	Ortho.
790.	Hydronephelite	$HNa_2Al_3Si_3O_{12} \cdot 3H_2O$	Ortho.
	b. Micas		
791.	Muscovite	$H_2KAl_3Si_3O_{12}$	Mono.
792.	Damourite	$H_2KAl_3Si_3O_{12}$	Mono.
793.	Margarodite	$H_2KAl_3Si_3O_{12}$	Mono.
794.	Gilbertite	$H_2KAl_3Si_3O_{12}$	Mono.
795.	Sericite	$H_2KAl_3Si_3O_{12}$	Scaly
796.	Fuchsite	$H_2KAl_3Si_3O_{12}+Cr$	Scaly
797.	Pinite	$H_2KAl_3Si_3O_{12}$	Amorph.
798.	Paragonite	$H_2NaAl_3(Si_3O_{12})_3$	Mono.
799.	Lepidolite	$(Li,K,Na)_2(Al,Fe)OH_2(SiO_3)_3$	Mono.
800.	Zinnwaldite	$H_2K_4Li_4Fe_3Al_8F_8Si_{14}O_{42}$	Mono.
801.	Biotite	$(H,K)_2(Mg,Fe)_4(Al,Fe)_2(SiO_4)_4$	Mono.
802.	Meroxene	$(H,K)_2(Mg,Fe)_4(Al,Fe)_2(SiO_4)_4+Fe$	Mono.
803.	Anomite	$(H,K)_2(Mg,Fe)_4(Al,Fe)_2(SiO_4)_4+Mn$	Mono.
804.	Haughtonite	$(H,K)_2(Mg,Fe)_4(Al,Fe)_2(SiO_4)_4+Mn$	Mono.
805.	Manganophyllite	$(H,K)_2(Mg,Fe)_4(Al,Fe)_2(SiO_4)_4+Mn$	Mono.
806.	Caswellite	$(H,K)_2(Mg,Fe)_4(Al,Fe)_2(SiO_4)_4+Fe$	Mono.
807.	Phlogopite	$(H,K)_2(Mg,Fe)_4(Al,Fe)_2(SiO_4)_4+Fe$	Mono.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
761.	White	3.5	2	New Jersey	Rock forming
762.	White	5	2	Strontian	
763.	White	4	2	Nova Scotia	
764.	Colorless	4	2	North Carolina	
765.	White	4	2	Ireland	
766.	White	4.5	2	New York	
767.	White	3.5	2	New York	
768.	Colorless	4.5	2	Mt. Albano	
769.	White	3.5	2	New Jersey	
770.	White	3.5	2	Mountains	
771.	White	3.5	2	Italy	
772.	White	4.5	2	Silesia	
773.	White	4	2	New Jersey	
774.	Red	4	2	Nova Scotia	
775.	Yellow	4	2	Maryland	
776.	Colorless	4	2	Bohemia	
777.	Colorless	4	2	Sicily	
778.	White	4.5	2	New Jersey	
779.	White	4	2	Colorado	
780.	Colorless	.....	2	France	
781.	Colorless	5	2	New Jersey	
782.	Colorless	5	1.9	New Jersey	
783.	White	4	2.6	Scotland	
784.	White	5	2	New Jersey	
785.	White	5	2	Southern Norway	
786.	White	5	2	Colorado	
787.	White	5	2	Colorado	
788.	White	5	2	Colorado	
789.	White	.....	2	Arkansas	
790.	White	4.5	2	Maine	
791.	Colorless	2	2.7	Maine	Electrical purposes and rock forming
792.	Colorless	2	2.7	Maine	
793.	Pearly	2	2.7	Tyrol	
794.	Whitish	2	2.7.	Cornwall	
795.	Whitish	2	2.7	Wiesbaden	
796.	Green	2	2.7	Zillerthal	
797.	Gray	2.5	2.6	Germany	
798.	Yellow	2.5	2.7	Pennsylvania	
799.	Red	2.5	2.8	Maine	
800.	Yellow	2.5	2.8	Zinnwald	
801.	Green	2.5	2.7	N. England States	
802.	Dark	2.5	2.7	Vesuvius	
803.	Dark	.....	......	New Jersey	
804.	....	.....	2.9	Sutherland	
805.	Red	2.5	2.7	Sweden	
806.	....	.....	......	New Jersey	
807.	Brown	2.5	2.7	New York	

	Composition	Form
VII. SILICATES—*continued*		
808. Lepidomelane	$(H,K)_2Fe_3(Fe,Al)_4(SiO_4)_5$	Mono.
809. Alurgite	$(H,K)_2Fe_3(Fe,Al)_4(SiO_4)_5+Mn$	Mono.
810. Roscoelite	$H_8K(Mg,Fe)(Al,V)_4(SiO_3)_{12}$	Mono.
811. Margarite	$H_2CaAl_4Si_2O_{12}$	Mono.
812. Seybertite	$H_3(Mg,Ca)_5Al_5Si_2O_{18}$	Mono.
813. Zanthophyllite	$H_8(Mg,Ca)_{14}Al_{16}Si_5O_{52}$	Mono.
814. Chloritoid	$H_2(Fe,Mg)Al_2SiO_7$	Mono.
815. Sismondine	$H_{14}Fe_7Al_{16}Si_8O_{54}$	Triclinic
816. Salmite	$H_{14}Fe_7Al_{16}Si_8O_{54}$	Triclinic
817. Masonite	$H_{14}Fe_7Al_{16}Si_8O_{54}$	Triclinic
818. Ottrelite	$H_2(Fe,Mn)Al_2Si_2O_9$	Mono.
819. Venasquite	$H_2FeAl_2Si_3O_{11}$	Mono.
820. Phyllite	$H_2FeAl_2Si_3O_{11}$	Mono.
821. Clinochlore	$H_8(Mg,Fe)_5Al_2Si_3O_{18}$	Mono.
822. Leuchtenbergite	$H_8(Mg,Fe)_5Al_2Si_3O_{18}$, lacks Fe	Mono.
823. Kotschubeite	$H_8(Mg,Fe)_5Al_2Si_3O_{18}+Cr$	Hexag.
824. Manganchlorite	$H_8(Mg,Fe)_5Al_2Si_3O_{18}+Mn$	Hexag.
825. Penninite	$H_8(Mg,Fe)_5Al_2Si_3O_{18}$	Mono.
826. Kämmererite	$H_8(Mg,Fe)_5Al_2Si_3O_{18}$	Mono.
827. Pseudophite	$H_8(Mg,Fe)_5Al_2Si_3O_{18}$	Massive
828. Prochlorite	$H_{40}(Fe,Mg)_{23}Al_{14}Si_{13}O_{90}$	Mono.
829. Corundophilite	$H_{20}Mg_{11}Al_8Si_6O_{45}$	Mono.
830. Amesite	$H_4(Mg,Fe)_2Al_2SiO_9$	Hexag.
831. Aphrosiderite	$H_{10}Fe_6(Fe,Al)_4Si_4O_{25}$	Hexag.
832. Diabantite	$H_{18}(Fe,Mg)_{12}Al_4Si_9O_{45}$	Hexag.
833. Delessite	$H_{10}(Mg,Fe)_4(Al,Fe)_4Si_4O_{23}$	Hexag.
834. Epichlorite	$H_7(Mg,K_2)_7(Al,Fe)_5Si_4O_{18}$	Hexag.
835. Euralite	$H_{16}(Mg,Fe,Ca)_9(Al,Fe)_4Si_9O_{37}$	Amorph.
836. Chlorophaeite	Fe,Mg,Mn,Ca, silicate	Amorph.
837. Hullite	Fe,Mg,Mn,Ca, silicate	Massive
838. Cronstedite	$H_6(Fe,Mg)_3Al_2Si_2O_{13}$	Hexag.
839. Thuringite	$H_{18}Fe_8(Al,Fe)_8Si_6O_{41}$	Massive
840. Chamosite	$H_6(Fe,Mg)_3Al_2Si_2O_{13}$	Oolitic
841. Stilpnomelane	$2(Mg,Fe)O\cdot(Fe,Al)_2O_3\cdot5SiO_2\cdot3H_2O$	Scaly
842. Strigovite	$H_4Fe_2(Al,Fe)_2Si_2O_{11}$	Hexag.
843. Rumpfite	$H_{28}Mg_7Al_{16}Si_{10}O_{65}$	Massive
844. Vermiculite	$H_{24}Mg_{12}(Al,Fe)_4Si_9O_{48}$	Crystal.
845. Jefferisite	$H_{12}Mg_4(Al,Fe,)_4Si_5O_{26}$	Crystal.
c. Serpentine, Talc		
846. Serpentine	$H_4Mg_3Si_2O_9$	Mono.
847. Bastite	$H_4Mg_3Si_2O_9$	Massive
848. Retinalite	$H_4Mg_3Si_2O_9+3$ per cent H_2O	Massive
849. Bowenite	$H_4Mg_3Si_2O_9$	Massive
850. Antigorite	$H_4Mg_3Si_2O_9$	Massive
851. Marmolite	$H_4Mg_3Si_2O_9$	Foliated
852. Chrysotile	$H_4Mg_3Si_2O_9$	Fibrous
853. Picrolite	$H_4Mg_3Si_2O_9$	Column.
854. Ophicalcite	$H_4Mg_3Si_2O_9+MgCaCO_3$	Massive

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
808.	Black	3	3	New York	Elec. purposes
809.	Red	2	2.9	Piedmont	
810.	Brown	1.5	2.9	California	Rock forming
811.	Grayish	3.5	2.9	North Carolina	
812.	Brown	4	3	New York	
813.	Bottle green	4	3	Ural Mts.	
814.	Gray	6.5	3.5	Michigan	
815.	Green	6.5	3.5	Switzerland	
816.	Green	6.5	3	Belgium	
817.	Green	6.5	3	Rhode Island	
818.	Gray	6	3	Luxembourg	
819.	Gray	5.5	3	Pyrenees Mts.	
820.	Gray	5.5	3	New England	
821.	Green	2	2.6	Pennsylvania	
822.	White	2	2.6	Ural Mts.	
823.	Red	2	2.6	Southern Urals	
824.	Reddish	.....	......	Sweden	
825.	Green	2	2.6	Zermatt	
826.	Reddish violet	2	2.6	Pennsylvania	
827.	Green	2	2.6	Pennsylvania	
828.	Green	1	2.7	North Carolina	
829.	Green	2.5	2.9	Massachusetts	
830.	Green	2.5	2.7	Italy	
831.	Green	.....	2.8	Colorado	
832.	Green	2	2.7	Connecticut	
833.	Blackish green	2.5	2.8	Nova Scotia	
834.	Green	2	2.7	Hartz	
835.	Green	2.5	2.6	Finland	
836.	Green	1.5	2	Scotland	
837.	Velvet black	2	2	Ireland	
838.	Black	3	3	Bohemia	
839.	Green	2.5	3	Arkansas	
840.	Gray	3	3	Chamoson	
841.	Black	3	2.7	Silesia	
842.	Green	1	3	Silesia	
843.	White	1.5	2.6	Upper Styria	
844.	Brown	1.5	2.7	Massachusetts	
845.	Brown	1.5	2.3	Massachusetts	
846.	Green	2.5	2.5	Maine	Rock forming
847.	....	.....	.....	....	
848.	Yellow	3.5	2.4	Tyrol	
849.	Green	5.5	2.5	Rhode Island	
850.	Green	2.5	2.6	Piedmont	
851.	White	4.5	2.4	New Jersey	
852.	White	.....	2.2	Canada	Cloth
853.	Green	2	2.5	Maryland	Rock forming
854.	Green	3	2.5	Pennsylvania	

		Composition	Form
VII.	Silicates—*continued*		
855.	Deweylite	$4MgO \cdot 3SiO_2 \cdot 6H_2O$	Amorph.
856.	Genthite	$2NiO \cdot 2MgO \cdot 3SiO_2 \cdot 6H_2O$	Amorph.
857.	Garnierite	$H_2(Ni,Mg)SiO_4 \cdot H_2O$	Amorph.
858.	Talc	$H_2Mg_3(SiO_3)_4$	Ortho.
859.	Steatite	$H_2Mg_3(SiO_3)_4$	Ortho.
860.	French chalk	$H_2Mg_3(SiO_3)_4$	Ortho.
861.	Rensselaerite	$H_2Mg_3(SiO_3)_4$	Ortho.
862.	Sepiolite	$H_4Mg_2Si_3O_{10}$	Earthy
863.	Connarite	$H_4Ni_2Si_3O_{10}$	Hexag.
864.	Spadaite	$5MgO \cdot 6SiO_2 \cdot 4H_2O$	Amorph.
865.	Saponite	Mg,Al,H, silicate	Amorph.
866.	Celadonite	Fe,Mg,K, silicate	Earthy
867.	Glauconite	Fe,K,H, silicate	Amorph.
868.	Pholidolite	$5H_2O \cdot K_2O \cdot 12(Fe,Mg)O \cdot Al_2O_3 \cdot 13SiO_2$	Amorph.
	d. Kaolins		
869.	Kaolinite	$H_4Al_2Si_2O_9$	Mono.
870.	Lithomarge	$H_4Al_2Si_2O_9$	Compact
871.	Pholerite	$H_4Al_2Si_2O_9$	Compact
872.	Halloysite	$(Al_2O_3 \cdot 2SiO_2)$	Massive
873.	Pseudosteatite	$(Al_2O_3 \cdot 2SiO_2)$	Massive
874.	Indianaite	$(Al_2O_3 \cdot 2SiO_2)$	Massive
875.	Smectite	$(Al_2O_3 \cdot 2SiO_2)$	Massive
876.	Bole	$(Al_2O_3 \cdot 2SiO_2)$	Massive
877.	Bergseife	$(Al_2O_3 \cdot 2SiO_2)$	Massive
878.	Newtonite	$H_8Al_2Si_2O_{11} \cdot nH_2O$	Hexag.
879.	Cimolite	$2Al_2O_3 \cdot 9SiO_2 \cdot 6H_2O$	Amorph.
880.	Montmorillonite	$H_2Al_2Si_4O_{12} \cdot nH_2O$	Massive
881.	Stolpenite	$H_2Al_2Si_4O_{12} \cdot nH_2O$	Massive
882.	Pyrophyllite	$H_2Al_2(SiO_3)_4$	Massive
883.	Allophane	$Al_2SiO_5 \cdot 5H_2O$	Amorph.
884.	Collyrite	$2Al_2O_3 \cdot SiO_2 \cdot 9H_2O$	Massive
885.	Schrotterite	$8Al_2O_3 \cdot 3SiO_2 \cdot 30H_2O$	Massive
886.	Cenosite	$H_4Ca_2(Y,Er)_2CSi_4O_{17}$	Ortho.
887.	Thaumasite	$CaSiO_3 \cdot CaCO_3 \cdot CaSO_4 \cdot 15H_2O$	Tetrag.
888.	Uranophane	$CaO \cdot 2UO_3 \cdot 2SiO_2 \cdot 6H_2O$	Ortho.
889.	Chrysocolla	$CuSiO_3 \cdot 2H_2O$	Amorph.
890.	Chloropal	$H_8Fe_2Si_3O_{12} \cdot 2H_2O$	Massive
891.	Nontronite	$H_8Fe_2Si_3O_{12} \cdot 2H_2O$	Massive
892.	Pinguite	$H_8Fe_2Si_3O_{12} \cdot 2H_2O$	Massive
893.	Graminite	$H_8Fe_2Si_3O_{12} \cdot 2H_2O$	Massive
894.	Hoeferite	$2Fe_2O_3 \cdot 4SiO_2 \cdot 7H_2O$	Amorph.
895.	Hisingerite	Fe,H, silicate	Amorph.
896.	Bementite	$2MnSiO_3 \cdot H_2O$	Foliated
897.	Caryopilite	$4MnO \cdot 3SiO_2 \cdot 3H_2O$	Massive
898.	Neotocite	FeMgH, silicate	Amorph.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
855.	Whitish	2	2	Maryland	Rock forming
856.	Green	3	2	Texas	
857.	Green	.....	2.3	North Carolina	Nickel
858.	Green	1	2.7	Vermont	Lubricants
859.	Gray	1	2.5	Virginia	Soapstone
860.	White	1	2.5	Virginia	Lubricants
861.	White	1	2.5	New York	
862.	White	2	2	Asia Minor	
863.	Green	2.5	2	Saxony	Nickel
864.	Reddish	2.5	......	Italy	Magnesium
865.	White	1	2	Scotland	Rock forming
866.	Green	1	......	Verona	
867.	Green	2	2	New Jersey	Fertilizer
868.	Yellow	2	2	Sweden	Rock forming
869.	White	2	2.6	Delaware	Brick, fire clay, pottery, and rock forming
870.	White	2	2	Germany	
871.	White	2	2	France	
872.	White	1	2	Illinois	
873.	Green	2	2	Illinois	
874.	White	2	2	Indiana	
875.	Greenish	2	2	France	
876.	Brown	2	2	Illinois	
877.	Brown	2	2	California	
878.	White	1	2	Arkansas	
879.	White	1	2	Argentina	
880.	White	1	2	St. Jean Ode-Cole	
881.	White	1	2	France	
882.	White	1	2.8	North Carolina	
883.	Blue	3	1.8	Pennsylvania	
884.	White	1	2	Pyrenees	
885.	Green	3	1.9	Alabama	
886.	Brown	5	3	Norway	
887.	White	3.5	1.8	New Jersey	
888.	Yellow	3.5	1.8	North Carolina	
889.	Green	2	2	New Jersey	
890.	Yellow	2.5	1.7	Pennsylvania	
891.	Yellow	2.5	1.7	France	
892.	Green	1	1.7	Saxony	
893.	Green	1	1.7	Menzenberg	
894.	Green	1	2.3	Bohemia	
895.	Black	3	2.5	Sweden	
896.	Yellow	1	2.9	New Jersey	
897.	Brown	3	2.8	Sweden	
898.	Black	3	2.6	Sweden	

	Composition	Form
VIIa. TITANATES		
899. Titanite	$CaTiSiO_5$	Mono.
900. Sphene	$CaTiSiO_5$	Mono.
901. Ligurite	$CaTiSiO_5$	Mono.
902. Spinthere	$CaTiSiO_5$	Mono.
903. Lederite	$CaTiSiO_5$	Mono.
904. Titanomorphite	$CaTiSiO_5$	Mono.
905. Greenovite	$CaTiSiO_5$	Mono.
906. Grothite	$CaTiSiO_5$	Mono.
907. Keilhauite	$15CaSiTiO_5 \cdot (Al,Fe,Y)_2(Si,Ti)O_5$	Mono.
908. Guarinite	$CaTiSiO_5$	Ortho.
909. Tscheffkinite	$15CaSiTiO_5 \cdot (Al,Fe,Y)_2(Si,Ti)O_5$	Massive
910. Astrophyllite	$(Na,K)_4(Fe,Mn)_4Ti(SiO_4)_4$	Ortho.
911. Johnstrupite	Ce,Ca,Na,Ti,Fe, silicate	Mono.
912. Mosandrite	Ce,Ca,Na,Ti,Fe, silicate	Prism.
913. Rinkite	Ce,Ca,Na,Ti,Fe, silicate	Mono.
914. Neptunite	Ce,Ca,Na,Ti,Fe, silicate	Mono.
915. Perovskite	$CaTiO_3$	Regular
916. Knopite	$CaTiO_3$, much Ce	Regular
917. Dysanalyte	$6(Ca,Fe)TiO_3 \cdot (Ca,Fe)Nb_2O_6$	Regular
918. Geikielite	$MgTiO_3$	Massive

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
899.	Brown	5	3	Massachusetts	Rock forming
900.	Brown	5	3	Massachusetts	
901.	Yellow	5	3	Massachusetts	
902.	Green	5	3	Massachusetts	
903.	Brown	5	3	Massachusetts	
904.	White	5	3	Massachusetts	
905.	Red	5	3	Massachusetts	
906.	Brown	6	3	Dresden	
907.	Black	6.5	3.5	Norway	
908.	Yellow	6	3	Mt. Somma	
909.	Black	5	4.5	Ilmen Mts.	
910.	Yellow	3	3	Colorado	
911.	Green	.....	3	Norway	
912.	Brown	4	2.9	Norway	
913.	Brown	5	3	Greenland	
914.	Black	5	3	South Greenland	
915.	Yellow	5.5	4	New York	
916.	Black	.....	......	Sweden	
917.	Black	5	4	Baden	
918.	Black	6	4	Ceylon	

	Composition	Form
VIII. NIOBATES, TANTALATES		
919. Pyrochlore	(G,Nb,Ti,Th,Ce,Ca,Fe,U,Mg,NaF,)·O	Regular
920. Hatchettolite	(G,Nb,Ti,Th,Ce,Ca,Fe,U,Mg,NaF,)·O	Regular
921. Microlite	$Ca_2Ta_2O_7$	Regular
922. Pyrrhite	$Ca_2Ta_2O_7$+Nb,Ti,Ce,Na	Regular
923. Fergusonite	(Y,Er,Ce)(Nb,Ta)O_4	Tetrag.
924. Sipylite	Er Nb O_4	Tetrag.
925. Columbite-tantalite	(Fe,Mn)(Nb,Ta)$_2O_6$	Ortho.
926. Tapiolite	Fe(Ta,Nb)$_2O_6$	Regular
927. Yttrotantalite	W,Sn,Y,Er,Ce,U,Fe,Ca,H,Nb, tantalate	Ortho.
928. Samarskite	G,Sn,W,U,Ce,Di,La,Y,Er,Fe,Mn,Ca, H,Nb, tantalate	Ortho.
929. Annerodite	Pyroniobate of U,Y	Ortho.
930. Hielmite	Y,Fe,Mn,Ca,Sn,Nb, tantalate	Ortho.
931. Aeschynite	Ce,Th,Fe,Ca,Nb, titanate	Ortho.
932. Polymignite	Ce,La,Di,Fe,Ca,Nb,Zn,Sn,Th, titanate	Ortho.
933. Euxenite	Y,Er,Ce,U,H,Nb, titnate	Ortho.
934. Polycrase	G,Nb,Y,Er,Ce,U,Fe,Ta,H_2O, titanate	Ortho.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
919.	Brown	5	4	Norway	Rock forming
920.	Brown	.....	4.7	North Carolina	
921.	Yellow	5.5	5	Massachusetts	
922.	Yellow	.....	......	Urals	
923.	Black	5.5	5.8	Carolinas	
924.	Black	6	4.8	Virginia	
925.	Iron black	6	5	N. England states	
926.	Black	6	7	Finland	
927.	Black	5	5.5	Sweden	
928.	Black	5	5.6	North Carolina	
929.	Black	6	5.7	Norway	
930.	Black	5	5.8	Sweden	
931.	Black	5	4.9	Ilmen Mts.	
932.	Black	6	4.7	Norway	
933.	Black	6.5	4.9	Norway	
934.	Black	5	4.9	South Carolina	

	Composition	Form
IX. PHOSPHATES, ARSENATES, ETC.		
1. *Anhydrous*		
935. Xenotime	YPO_4	Tetrag.
936. Monazite	$(Ce,La,Di)PO_4$	Mono.
937. Berzeliite	$(CaMgMn)_3As_2O_8$	Regular
938. Monimolite	$(Pb,Fe,Ca)_3Sb_2O_8$	Regular
939. Carminite	$Pb_3As_2O_8 \cdot 10FeAsO_4$	Ortho.
940. Pucherite	$BiVO_4$	Ortho.
941. Triphylite	$LiFePO_4$	Ortho.
942. Lithiophilite	$LiMnPO_4$	Ortho.
943. Natrophilite	$NaMnPO_4$	....
944. Beryllonite	$NaBePO_4$	Ortho.
945. Apatite	$(CaF,Cl)Ca_4(PO_4)_3$	Hexag.
946. Moroxite	$(CaF,Cl)Ca_4(PO_4)_3$	Hexag.
947. Lasurapatite	$(CaF,Cl)Ca_4(PO_4)_3$	Hexag.
948. Francolite	$(CaF,Cl)Ca_4(PO_4)_3$	Hexag.
949. Manganapatite	$(CaF,Cl)Ca_4(PO_4)_3+Mn$	Hexag.
950. Phosphorite	$(CaF,Cl)Ca_4(PO_4)_3$	Concret.
951. Eupyrchroite	$(CaF,Cl)Ca_4(PO_4)_3$	Concret.
952. Staffelite	$(CaF,Cl)Ca_4(PO_4)_3$	Concret.
953. Earthy apatite; osteolite	Altered apatite	Earthy
954. Pyromorphite	$(PbCl)Pb_4(PO_4)_3$	Hexag.
955. Polysphaerite	$(PbCl)Pb_4(CO_4)_3+Ca$	Hexag.
956. Miesite	$(PbCl)Pb_4(PO_4)_3+Ca$	Hexag.
957. Nussierite	Impure polysphaerite	....
958. Mimetite	$(PbCl)Pb_4(AsO_4)_3$	Hexag.
959. Campylite	$(PbCl)Pb_4(AsO_4)_3+P$	Hexag.
960. Endlichite	$Pb_5Cl(As,VO_4)_3$	Hexag.
961. Vanadinite	$(PbCl)Pb_4(VO_4)_3$	Hexag.
962. Hedyphane	$(Pb,Ca,Ce)_4(AsO_4)_3$	Mono.
963. Svabite	$Ca(F,Cl,OH)Ca_4(AsO_4)_3$	Hexag.
964. Wagnerite	$(MgF)MgPO_4$	Mono.
965. Spodiosite	$(CaF)CaPO_4$	Mono.
966. Triplite	$(Fe,Mn)PO_4$	Mono.
967. Talktriplite	$(Fe,Mn,Ca,Mg)PO_4$	Mono.
968. Triploidite	$(Fe_3,Mn,OH)PO_4$	Mono.
969. Adelite	$(MgOH)CaAsO_4$	Mono.
970. Tilasite	$(Mg,FOH)CaAsO_4$	Mono.
971. Sarkinite	$(MnOH)MnAsO_4$	Mono.
972. Herderite	$(CaF)BePO_4$	Mono.
973. Hamlinite	$Al_3Sr(OH)_7P_2O_7$	Hexag.
974. Durangite	$Na(AlF)AsO_4$	Mono.
975. Amblygonite	$Li(AlF)PO_4$	Triclinic
2. *Basic*		
976. Olivenite	$Cu_3As_2O_8 \cdot Cu(OH)_2$	Ortho.
977. Libethenite	$Cu_3P_2O_8 \cdot Cu(OH)_2$	Ortho.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
935.	Brown	4	4	Georgia	Rock forming
936.	Red	5	4.9	Connecticut	
937.	Yellow	5	4	Sweden	
938.	Brown	.....	6.5	Pajsberg	
939.	Red	2.5	4	Nassau	
940.	Brown	4	6	Saxony	
941.	Gray	4.5	3	Massachusetts	
942.	Yellow	4.5	3	Connecticut	
943.	Wine yellow	4.5	3	Connecticut	
944.	Colorless	5.5	2.8	Maine	
945.	Green	5	3	Maine	Phosphorus
946.	Blue	5	3	Arendal	
947.	Sky blue	5	3	Siberia	
948.	Grayish green	5	3	England	
949.	Green	5	3	Delaware	
950.	Green	5	3	Spain	
951.	Gray	4.5	3	New York	
952.	Yellow	4	3	Staffel	
953.	Green	3.5	6.5	New York	
954.	Green	3.5	6.5	Pennsylvania	Lead
955.	Brown	.....	5.8	Cornwall	
956.	Brown	.....	5	Bohemia	
957.	Yellow	.....	5	France	
958.	Yellow	3.5	7	Pennsylvania	
959.	Brown	.....	7	Cumberland	
960.	Brown	2.7	6.6	Arizona	
961.	Red	2.7	6.6	Arizona	
962.	White	4	5	Sweden	
963.	Colorless	5	3.5	Sweden	Rock forming
964.	White	5	3	Austria	
965.	Ash gray	5	2.9	Sweden	
966.	Gray	4	3	Connecticut	Phosphorus
967.	Gray	4	3	Horrsjoberg	
968.	Brown	4.5	3.6	Connecticut	
969.	Yellow	5	3.7	Sweden	
970.	Yellow	5	3.7	Langban	Rock forming
971.	Red	4	4	Sweden	Manganese
972.	White	5	2.9	Maine	
973.	Colorless	4.5	3	Maine	
974.	Orange red	.....	3.9	Mexico	Arsenic
975.	White	6	3	Maine	Phosphorus
976.	Green	3	4	Utah	Copper
977.	Green	4	3.6	Cornwall	

COMPREHENSIVE

		Composition	Form
IX.	PHOSPHATES, ARSENATES—*continued*		
978.	Tarbuttite	$Zn_3P_2O_8 \cdot Zn(OH)_2$	Triclinic
979.	Adamite	$Zn_3As_2O_8 \cdot Zn(OH)_2$	Ortho.
980.	Descloizite	$(Pb,Zn)_2(OH)VO_4$	Ortho.
981.	Eusynchite	$PbZnCuV_2O_8$	Massive
982.	Dechenite	PbV_2O_6	Massive
983.	Calciovolborthite	$(Cu,Ca)_3V_2O_8 \cdot (Cu,Ca)(OH)_2$	Ortho.
984.	Brackebuschite	$(Pb,Fe,Mn)_3V_2O_8 \cdot H_2O$	Mono.
985.	Psittacinite	$(Pb,Cu)_4(OH)_2V_2O_8 \cdot H_2O$	Coatings
986.	Mottramite	$(Pb,Cu)_4(OH)_2V_2O_8 \cdot H_2O$	Coatings
987.	Clinoclasite	$Cu_3As_2O_8 \cdot 3Cu(OH)_2$	Mono.
988.	Erinite	$Cu_3As_2O_8 \cdot 2Cu(OH)_2$	Concent.
989.	Dihydrite	$Cu_3P_2O_8 \cdot 2Cu(OH)_2$	Mono.
990.	Pseudomalachite	$Cu_3P_2O_8 \cdot 3Cu(OH)_2$	Massive
991.	Chondrarsenite	$Mn_3As_2O_8 \cdot 3Mn(OH)_2$	Mono.
992.	Xantharsenite	$Mn_3As_2O_8 \cdot 3Mn(OH)_2 + H_2O$	Mono.
993.	Dufrenite	$FePO_4 \cdot Fe(OH)_3$	Ortho.
994.	Lazulite	$(Fe,Mn)Al_2(OH)PO_4$	Mono.
995.	Tavistockite	$Ca_3P_2O_3 \cdot 2Al(OH)_2$	Mono.
996.	Cirrolite	$Ca_3Al(PO_4)_3 \cdot Al(OH)_3$	Mono.
997.	Arseniosiderite	$Ca_3Fe(AsO_4)_3 \cdot 3Fe(OH)_3$	Tetrag.
998.	Allacite	$Mn_3As_2O_8 \cdot 4Mn(OH)_2$	Mono.
999.	Synadelphite	$2(Al,Mn)AsO_4 \cdot 5Mn(OH)_2$	Mono.
1000.	Flinkite	$MnAsO_4 \cdot 2Mn(OH)_2$	Ortho.
1001.	Hematolite	$(Al,Mn)AsO_4 \cdot 4Mn(OH)_2$	Hexag.
1002.	Retzian	Mn,Ca,Ce,Li,Ca,Mg, arsenate	Ortho.
1003.	Arseniopleite	Sb,Fe,Mn,Pb,Ca,Mg,HSP, arsenate	Hexag.
1004.	Manganostibiite	$10MnO \cdot (Sb,As)_2O_5$	Ortho.
1005.	Atelestite	$H_2Bi_3AsO_8$	Mono.
3.	*Normal Hydrous*		
1006.	Struvite	$(NH_4)MgPO_4 \cdot 6H_2O$	Ortho.
1007.	Collophanite	$Ca_3P_2O_8 \cdot H_2O$	Amor.
1008.	Pyrophosphorite	$Mg_2P_2O_7 \cdot 4(Ca_3P_2O_8 + Ca_2P_2O_7)$	Massive
1009.	Hopeite	$Zn_3P_2O_8 \cdot H_2O$	Ortho.
1010.	Dickinsonite	$(Mn,Ca,Fe,Na_2)_3(PO_4)_2 \cdot \frac{3}{4}H_2O$	Hexag.
1011.	Fillowite	Fe,Mn,Ca,Na,Li, hydrous phosphate	Mono.
1012.	Roselite	$(Ca,Co,Mg)_3As_2O_8 \cdot 2H_2O$	Triclinic
1013.	Brandite	$Ca_2MnAs_2O_8 \cdot 2H_2O$	Triclinic
1014.	Fairfieldite	$Ca_2MnP_2O_8 \cdot 2H_2O$	Triclinic
1015.	Messelite	$(Ca,Fe)_3P_2O_8 \cdot 2\frac{1}{2}H_2O$	Triclinic
1016.	Reddingite	$Mn_3P_2O_8 \cdot 3H_2O$	Ortho.
1017.	Picropharmacolite	$(Ca,Mg)_3As_2O_8 \cdot 6H_2O$	Ortho.
1018.	Trichalcite	$Cu_3As_2O_8 \cdot 5H_2O$	Ortho.
1019.	Vivianite	$Fe_3P_2O_8 \cdot 8H_2O$	Mono.
1020.	Symplesite	$Fe_3As_2O_8 \cdot 8H_2O$	Mono.
1021.	Bobierrite	$Mg_3P_2O_8 \cdot 8H_2O$	Mono.
1022.	Hoernesite	$Mg_3As_2O_8 \cdot 8H_2O$	Mono.
1023.	Erythrite	$Co_3As_2O_8 \cdot 8H_2O$	Mono.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
978.	Brown	3.5	4	Rhodesia	Zinc
979.	Yellow	3.5	4	Chile	
980.	Red	3.5	5.9	Arizona	Lead
981.	Red	3	5.5	Baden	Vanadium
982.	Red	3	5.6	Bavaria	
983.	Green	3	3.8	Thuringa	
984.	Black	.....	......	Argentina	
985.	Green	.....	......	Montana	
986.	Black	.....	......	England	
987.	Green	2.5	4	Cornwall	Copper
988.	Green	4	4	Cornwall	
989.	Green	4.5	4	Urals	
990.	Dark green	4	3	Rheinbreitenbach	
991.	Yellow	3	......	Sweden	Manganese
992.	Yellow	.....	......	Sweden	
993.	Green	3.5	3	New York	Phosphorus
994.	Blue	5	3	North Carolina	Gems
995.	White	.....	......	Devonshire	Phosphorus
996.	Yellow	5	3	Sweden	
997.	Brown	1	3	France	Arsenic
998.	Red	4	3	Sweden	Manganese
999.	Black	4	3	Sweden	
1000.	Brown	4	3.8	Sweden	
1001.	Red	3.5	3	Nordmark	
1002.	Brown	4	4	Nordmark	Arsenic
1003.	Red	4	......	Sweden	Arsenic
1004.	Black	.....	......	Sweden	Manganese
1005.	Yellow	3	6	Saxony	Bismuth
1006.	White	2	1.6	Victoria	Lead
1007.	Colorless	2	2	Sombrero Islands	Phosphorus
1008.	White	3	2	West Indies	
1009.	White	2.5	2.7	Altenberg	Zinc
1010.	Green	3.5	3	Connecticut	Phosphorus
1011.	Yellow	4	3	Connecticut	
1012.	Red	3	3.5	Saxony	Arsenic
1013.	Colorless	5	3.6	Sweden	
1014.	White	3.5	3	Connecticut	Phosphorus
1015.	Colorless	3.5	......	Hesse	
1016.	White	3	3	Connecticut	
1017.	White	.....	......	Missouri	Arsenic
1018.	Green	2	......	Turginsk	Copper
1019.	Colorless	1.5	2.5	New Jersey	Phosphorus
1020.	Indigo	2.5	2.9	Carinthia	Arsenic
1021.	Colorless	.....	......	Norway	Phosphorus
1022.	White	1	2.4	Hungary	Arsenic
1023.	Red	1.5	2.9	California	

		Composition	Form
IX.	PHOSPHATES, ARSENATES—*continued*		
1024.	Annabergite	$Ni_3As_2O_8 \cdot 8H_2O$	Mono.
1025.	Cabrerite	$(Ni,Mg)_3As_2O_8 \cdot 8H_2O$	Mono.
1026.	Kottigite	$Zn_3As_2O_8 \cdot 8H_2O$	Mono.
1027.	Rhabdophanite	$(Y,Er)_2O_3 \cdot (La,Di)_2O_3 \cdot P_2O_3 \cdot H_2O$	Mono.
1028.	Churchite	$Ce_2O_3 \cdot CaO \cdot PD_2O_5H_2O$	Mono.
1029.	Scorodite	$FeAsO_4 \cdot 2H_2O$	Ortho.
1030.	Strengite	$FePO_4 \cdot 2H_2O$	Ortho.
1031.	Phosphosiderite	$2FePO_4 \cdot 3\frac{1}{2}H_2O$	Ortho.
1032.	Barrandite	$(Al,Fe)PO_4 \cdot 2H_2O$	Ortho.
1033.	Variscite	$AlPO_4 \cdot 2H_2O$	Ortho.
1034.	Callanite	$AlPO_4 \cdot 2\frac{1}{2}H_2O$	Ortho.
1035.	Zepharovichite	$AlPO_4 \cdot 3H_2O$	Ortho.
1036.	Koninckite	$FePO_4 \cdot 3H_2O$	Ortho.
	4. *Acid Hydrous*		
1037.	Pharmacolite	$HCaAsO_4 \cdot 2H_2O$	Mono.
1038.	Haidingerite	$HCaAsO_4 \cdot H_2O$	Ortho.
1039.	Wapplerite	$HCaAsO_4 \cdot 3\frac{1}{2}H_2O$	Mono.
1040.	Brushite	$HCaPO_4 \cdot 2H_2O$	Mono.
1041.	Martinite	$H_2Ca_5(PO_4)_4 \cdot \frac{1}{2}H_2O$	Hexag.
1042.	Newberyite	$HMgPO_4 \cdot 3H_2O$	Ortho.
1042½.	Stercorite	$HNa(NH_4)PO_4 \cdot 4H_2O$	Mono.
1043.	Hureaulite	$H_2Mn_5(PO_4)_4 \cdot 4H_2O$	Mono.
1044.	Forbesite	$H_2(Ni,Co)_2As_2O_8 \cdot 8H_2O$	Mono.
	5. *Basic Hydrous*		
1045.	Isoclasite	$Ca_3P_2O_8 \cdot Ca(OH)_2 \cdot 4H_2O$	Mono.
1046.	Hemafibrite	$Mn_3As_2O_8 \cdot 3Mn(OH)_2 \cdot 2H_2O$	Ortho.
1047.	Euchroite	$Cu_3As_2O_8 \cdot Cu(OH)_2 \cdot 6H_2O$	Ortho.
1048.	Conichalcite	$(Cu,Ca)_3As_2O_8 \cdot (Cu,Ca)(OH)_2 \cdot \frac{1}{2}H_2O$	Ortho.
1049.	Bayldonite	$(Pb,Cu)_3As_2O_8 \cdot (Pb,Cu)(OH)_2 \cdot H_2O$	Mono.
1050.	Tagilite	$Cu_3P_2O_8Cu(OH) \cdot 2H_2O$	Mono.
1051.	Leucochalcite	$Cu_3As_2O_8 \cdot Cu(OH)_2 \cdot 2H_2O$	Mono.
1052.	Volborthite	$(Cu,Ca,Ba)_3(OH)_3VO_4 \cdot 6H_2O$	Ortho.
1053.	Cornwallite	$Cu_3As_2O_8 \cdot 2Cu(OH)_2 \cdot H_2O$	Ortho.
1054.	Tyrolite	$Cu_3As_2O_8 \cdot 2Cu(OH)_2 \cdot 7H_2O$	Ortho.
1055.	Chalcophyllite	$7CuO \cdot As_2O_514H_2O$	Hexag.
1056.	Veszelyite	$7(Zn,Cu_5)(P,AS)_2O_5 \cdot 9H_2O$	Mono.
1057.	Wavellite	$4AlPO_4 \cdot 2Al(OH)_3 \cdot 9H_2O$	Ortho.
1058.	Fischerite	$AlPO_4 \cdot Al(OH)_3 \cdot 2\frac{1}{2}H_2O$	Ortho.
1059.	Peganite	$Al(PO_4) \cdot Al(OH)_3 \cdot 1\frac{1}{2}H_2O$	Orhto.
1060.	Turquois	$AlPO_4 \cdot Al(OH)_3 \cdot H_2O$	Amorph.
1061.	Wardite	$2Al_2O_3 \cdot P_2O_5 \cdot 4H_2O$	Crusting
1062.	Sphaerite	$4AlPO_4 \cdot 6Al(OH)_3$	Ortho.
1063.	Liskeardite	$(Al,Fe)AsO_4 \cdot 2(Al,Fe)(OH)_3 \cdot 5H_2O$	Ortho.
1064.	Evansite	$2AlPO_4 \cdot 4Al(OH)_3 \cdot 12H_2O$	Ortho.
1065.	Coeruleolactite	$3Al_2O_32P_2O_5 \cdot 10H_2O$	....
1066.	Augelite	$2Al_2O_3 \cdot P_2O_5 \cdot 3H_2O$	Mono.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
1024.	Green	2	......	Nevada	Arsenic
1025.	Green	2	2.9	Spain	
1026.	Red	2.5	3	Schneeberg	
1027.	Brown	3.5	3.9	Cornwall	Rare elements
1028.	Smoke gray	3.5	3	Cornwall	Cerium
1029.	Green	3.5	3	Utah	Arsenic
1030.	Red	3	2.8	Virginia	Phosphorus
1031.	Red	3.7	2.7	Germany	
1032.	Gray	4.5	2.5	Bohemia	
1033.	Green	4	......	Utah	
1034.	Green	3.5	2.5	Lockmariaquer	
1035.	White	5.5	2.3	Bohemia	
1036.	Yellow	3.5	2.3	Belgium	
1037.	White	2	2.6	Joachimsthal	Arsenic
1038.	White	1.5	2	Joachimsthal	Rock forming
1039.	Colorless	2	2	Joachimsthal	Arsenic
1040.	Colorless	2	2	Caribbean Sea	Phosphorus
1041.	Yellowish	2.8	......	Western India	
1042.	White	3	2	Victoria	
1042½.	White	2	1.6	Peru	
1043.	Yellow	5	3	Connecticut	
1044.	White	2.5	3	Atacama	Arsenic
1045.	White	1	2.9	Joachimsthal	Calcium
1046.	Red	3	3.5	Sweden	Manganese
1047.	Green	3.5	3	Hungary	Copper
1048.	Green	4	4	Utah	
1049.	Green	4	5	Cornwall	
1050.	Green	3	4	Urals	
1051.	White	.....	......	Germany	
1052.	Green	3	3	Urals	
1053.	Green	4	4	Cornwall	
1054.	Green	1	3	Utah	
1055.	Green	2	2	Utah	
1056.	Blue	3.5	3.5	Banat	
1057.	White	3	2	Saxony	Phosphorus
1058.	Green	5	2.4	Urals	
1059.	Green	3	2.4	Saxony	
1060.	Green	6	2.6	New Mexico	Gems
1061.	Green	5	2.7	Utah	Phosphorus
1062.	Gray	4	2.5	Bohemia	Aluminum
1063.	White	.....	......	Cornwall	
1064.	Colorless	4	1.9	Hungary	
1065.	White	.....	......	Pennsylvania	
1066.	Colorless	.....	2.7	Sweden	

	Composition	Form
IX. PHOSPHATES, ARSENATES—*continued*		
1067. Berlinite	$2Al_2 \cdot O_3 2P_2O_5 \cdot H_2O$	Massive
1068. Trolleite	$4Al_2O_3 \cdot 3P_2O_5 \cdot 3H_2O$	Compact
1069. Attacolite	$P_2O_5 \cdot Al_2 \cdot O_3$,MnO,CaO,$H_2O$, etc.	Massive
1070. Pharmacosiderite	$6FeAsO_4 \cdot 2Fe(OH)_3 \cdot 12H_2O$	Regular
1071. Ludlamite	$2Fe_3P_2O_8Fe(OH)_2 \cdot 8H_2O$	Mono.
1072. Cacoxenite	$FePO_4Fe(OH)_3 \cdot 4\frac{1}{2}H_2O$	Tufts
1073. Beraunite	$2FePO_4 \cdot Fe(OH)_3 \cdot 2\frac{1}{2}H_2O$	Mono.
1074. Childrenite	$2AlPO_4 \cdot 2Fe(OH)_2 \cdot 2H_2O$	Ortho.
1075. Eosphorite	$2AlPO_4 \cdot 2Fe(OH)_2 \cdot 2H_2O$	Ortho.
1076. Masapilite	$Ca_3Fe_2(AsO_4)_4 \cdot 2FeO(OH) \cdot 5H_2O$	Ortho.
1077. Calcioferrite	$Ca_3Fe_2(PO_4)_4 \cdot Fe(OH)_3 \cdot 8H_2O$	Mono.
1078. Borickite	$Ca_3Fe_2(PO_4)_4 \cdot 12Fe(OH)_3 \cdot 6H_2O$	Mono.
1079. Richellite	$4FeP_2O_8 \cdot Fe_2OF_2(OH)_2 \cdot 36H_2O$	Mono.
1080. Liroconite	$Cu_6Al(AsO_4)_5 \cdot 3CuAl(OH)_5 \cdot 20H_2O$	Mono.
1081. Chenevixite	$Cu_2(FeO)_2As_2O_8 \cdot 3H_2O$	Mono.
1082. Henwoodite	Fe,Cu,Ca,Al,H, phosphate	Mono.
1083. Chalcosiderite	$CuO \cdot 3Fe_2O_3 \cdot 2P_2O_5 \cdot 8H_2O$	Triclinic
1084. Andrewsite	$5Fe_2O_3 \cdot P_2O_5 \cdot 5H_2O$	Triclinic
1085. Kehoeite	Fe,Zn,Ca,Mg,Al,H, phosphate	Amorph.
1086. Goyazite	$Ca_3Al_{10}P_2O_{23} \cdot 9H_2O$	Tetrag.
1087. Plumbogummite	$PbO \cdot 2Al_2O_3 \cdot P_2O_5 \cdot 9H_2O$	Hexag.
1088. Torbernite	$Cu(UO_2)_2P_2O_8 \cdot 8H_2O$	Tetrag.
1089. Zeunerite	$Cu(UO_2)_2As_2O_8 \cdot 8H_2O$	Tetrag.
1090. Autunite	$Ca(UO_2)_2P_2O_8 \cdot 8H_2O$	Ortho.
1091. Uranospinite	$Ca(UO_2)_2As_2O_8 \cdot 8H_2O$	Ortho.
1092. Uranocircite	$Ba(UO_2)_2P_2O_8 \cdot 8H_2O$	Ortho.
1093. Phosphuranylite	$(UO_2)_3P_2O_8 \cdot 6H_2O$	Powder
1094. Trögerite	$(UO_2)_3As_2O_8 \cdot 12H_2O$	Mono.
1095. Walpurgite	$Bi_{10}(UO_2)_3(OH)_{24}(AsO_4)_4$	Triclinic
1096. Rhagite	$2BiAsO_4 \cdot 3Bi(OH)_3$	Triclinic
1097. Mixite	$20CuO \cdot Bi_2O_3 \cdot 5As_2O_5 \cdot 22H_2O$	....
6. *Antimonates*		
1098. Atopite	$Ca_2Sb_2O_7$	Regular
1099. Bindheimite	$Pb_3Sb_2O_8 \cdot 4H_2O$	Amorph.
1100. Romeite	$CaSb_2O_4$	Tetrag.
1101. Nadorite	$PbClSbO_2$	Ortho.
1102. Ecdemite	$Pb_4As_2O_7 \cdot 2PbCl_2$	Tetrag.
1103. Ochrolite	$Pb_4Sb_2O_7 \cdot 2PbCl_2$	Ortho.
1103*a*. Trippkeite	CuO,AS_2O_3	Tetrag.
1104. Tripuhyite	$2FeO \cdot Sb_2O_5$	Ortho.
1105. Derbylite	$FeO \cdot Sb_2O_5 \cdot 5FeO \cdot TiO_2$	Ortho.
1106. Lewisite	$5CaO \cdot 2TiO_2 \cdot 3Sb_2O_5$	Regular
1107. Mauzeliite	Pb,Ca,Ti, antimonate	Regular
1108. Ammiolite	Cu,Hg,Fe,S, antimonate	Earthy

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
1067.	Colorless	6	2.6	Germany	Phosphorus
1068.	Green	5.5	3	Sweden	
1069.	Salmon red	5	3	....	
1070.	Green	2.5	2.9	Utah	Arsenic
1071.	Green	3	3	Cornwall	Phosphorus
1072.	Yellow	3	3	Pennsylvania	
1073.	Brown	.....	......	Bohemia	
1074.	White	4.5	3	Maine	
1075.	Pink	4.5	3	Connecticut	
1076.	Black	4.5	3.5	Mexico	Arsenic
1077.	Yellow	2	2	Bavaria	Phosphorus
1078.	Brown	3.5	2.6	Bohemia	
1079.	Yellow	2	2	Belgium	
1080.	Blue	2	2.8	Cornwall	Arsenic
1081.	Green	3.5	3.9	Utah	
1082.	Blue	4	2.6	Cornwall	Phosphorus
1083.	Green	4	3	Cornwall	
1084.	Bluish green	4	3	Cornwall	
1085.	....	.....	2.3	South Dakota	
1086.	White	5	3	Brazil	
1087.	Yellowish	4	4	Brittany	Lead
1088.	Green	2	3	Cornwall	Uranium
1089.	Green	2	3	Cornwall	
1090.	Yellow	2	3	North Carolina	
1091.	Green	2	3	Saxony	
1092.	Green	.....	3.5	Voigtland	
1093.	Yellow	.....	......	North Carolina	
1094.	Yellow	.....	3	Saxony	
1095.	Yellow	3.5	5.7	Saxony	Bismuth
1096.	Yellow	5	6	Saxony	
1097.	Green	3.5	5	Utah	Copper
1098.	Yellow	5.5	5	Sweden	Antimony
1099.	Gray	4	4	Arkansas	Lead
1100.	Yellow	5.5	4.7	Piedmont	Antimony
1101.	Yellow	3.5	7	Algeria	Lead
1102.	Yellow	2.5	7	Sweden	
1103.	Yellow	.....	......	Chile	
1103*a*.	Bluish green	.....	......	Brazil	Copper
1104.	Greenish yellow	.....	5	Brazil	Antimony
1105.	Black	5	4	Brazil	Titanium
1106.	Yellow	.....	4	Brazil	Antimony
1107.	Brown	6	5	Sweden	
1108.	Scarlet	.....	......	Chile	

		Composition	Form
IX.	PHOSPHATES, ARSENATES—*continued*		
7.	*Mixed Phosphates*		
1109.	Diadochite	$2Fe_2O_3\cdot 2SO_3\cdot P_2O_5\cdot 12H_2O$	Mono.
1110.	Destinezite	$2Fe_2O_3\cdot 2SO_3\cdot P_2O_5\cdot 12H_2O$	Earthy
1111.	Pitticite	Fe,S, arsenate	Massive
1112.	Svanbergite	Ca,Al,S, phosphate	Hexag.
1113.	Beudantite	Fe,Pb,S,AS, phosphate	Hexag.
1114.	Lindackerite	$3NiO\cdot 6CuO\cdot SO_3 2As_2O_5\cdot 7H_2O$	Ortho.
1115.	Lünebergite	$3MgO\cdot B_2O_3\cdot P_2O_5\cdot 8H_2O$	Earthy
1116.	Lossenite	$2PbSO_4\cdot 3(FeOH)_3As_2O_8\cdot 12H_2O$	Ortho.
	8. *Nitrates, etc.*		
1117.	Soda niter	$NaNO_3$	Hexag.
1118.	Niter	KNO_3	Ortho.
1119.	Nitrocalcite	$Ca(NO_3)_2\cdot nH_2O$	....
1120.	Nitromagnesite	$Mg(NO_3)_2\cdot nH_2O$	....
1121.	Nitrobarite	$Ba(NO_3)_2$	Regular
1122.	Gerhardtite	$Cu(NO_3)_2\cdot 3Cu(OH)_2$	Ortho.
1123.	Darapskite	$NaNO_3\cdot Na_2SO_4\cdot H_2O$	Tetrag.
1124.	Nitroglauberite	$6NaNO_3\cdot 2Na_2SO_4\cdot 3H_2O$	Tetrag.
1125.	Lautarite	$Ca(IO_3)_2$	Mono.
1126.	Dietzeite	$7Ca(IO_3)2\cdot 8CaCrO_4$	Mono.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
1109.	Yellowish	3	2	Thuringia	Phosphorus
1110.	Yellowish	.....	......	Belgium	Arsenic
1111.	Brown	2	2	Saxony	
1112.	Yellow	5	3	Sweden	Phosphorus
1113.	Green	4	4	Cork	Lead
1114.	Green	2.5	......	Joachimsthal	Copper
1115.	....	.....	2	Hannover	Phosphorus
1116.	Brownish	.....	......	Greece	Arsenic
1117.	White	1.5	2	Nevada	Fertilizer
1118.	White	2	2	Egypt	
1119.	Gray	.....	......	Kentucky	
1120.	White	.....	......	Kentucky	
1121.	Colorless	.....	......	Chile	
1122.	Green	2	3	Arizona	Copper
1123.	Colorless	.....	......	Chile	Soda
1124.	White	.....	......	Atacama	Sodium
1125.	Colorless	.....	4.5	Atacama	Iodine
1126.	Yellow	3	3.7	Atacama	

	Composition	Form
X. Borates, etc.		
1127. Sussexite	$2(Mn,Zn,Mg)O \cdot B_2O_3 \cdot H_2O$	Ortho.
1128. Ludwigite	$3MgO \cdot B_2O_3 \cdot FeO \cdot Fe_2O_3$	Ortho.
1129. Pinakiolite	$3MgO \cdot B_2O_3 \cdot MnO \cdot Mn_2O_3$	Ortho.
1130. Nordenskiöldine	$CaSn(BO_3)_2$	Regular
1131. Jeremejevite	$AlBO_3$	Hexag.
1132. Hambergite	$Be_2(OH)BO_3$	Ortho.
1133. Szaibelyite	$2Mg_5B_4O_{11} \cdot 3H_2O$	Ortho.
1134. Boracite	$Mg_7Cl_2B_{16}O_{30}$	Regular
1135. Ascharite	$3Mg_2B_2O_5 \cdot 2H_2O$	Amorph.
1136. Rhodizite	K,Al,Cs,Rb,Na,Ca,Mg,Al, borate	Regular
1137. Warwickite	$6MgO \cdot FeO \cdot 2TiO_2 \cdot 3B_2O_3$	Ortho.
1138. Howlite	$H_5Ca_2B_5SiO_{14}$	Ortho.
1139. Lagonite	$Fe_2O_3 \cdot 3B_2O_3 \cdot 3H_2O$	Earthy
1140. Larderellite	$(NH_4)_2O \cdot 4B_2O_3 \cdot 4H_2O$	Mono.
1141. Colemanite	$Ca_2B_6O_{11} \cdot 5H_2O$	Mono.
1142. Pinnoite	$MgB_2O_4 \cdot 3H_2O$	Tetrag.
1143. Heintzite	$K_2O \cdot 4MgO \cdot 9B_2O_3 \cdot 16H_2O$	Mono.
1144. Borax	$Na_2B_4O_7 \cdot 10H_2O$	Mono.
1145. Ulexite	$NaCaB_5O_9 \cdot 8H_2O$	Fibers
1146. Bechilite	$CaB_4O_7 \cdot 4H_2O$	Crusts
1147. Hydroboracite	$CaMgB_6O_{11} \cdot 6H_2O$	Mono.
1148. Sulfoborite	$3MgSO_4 \cdot 2Mg_3B_4O_9 \cdot 12H_2O$	Ortho.
1149. Uraninite	Pb,Th,G,Ce,La,Y,Ca,N,Fe,H, uranite	Regular
1150. Uranniobite	Pb,Th,G,Ce,La,Y,Ca,N,Fe,H, uranite	Regular
1151. Bröggerite	Pb,Th,G,Ce,La,Y,Ca,N,Fe,H, uranite	Regular
1152. Cleveite	Pb,Th,G,Ce,La,Y,Ca,N,Fe,H, more U	Regular
1153. Nivenite	Pb,Th,G,Ce,La,Y,Ca,N,Fe,H, more U	Regular
1154. Pitchblende	Pb,Th,G,Ce,La,Y,Ca,N,Fe,H,more U	Regular
1155. Carnotite	$K_2O \cdot 2U_2O_3 \cdot V_2O_5 \cdot 3H_2O$	Earthy
1156. Gummite	$(Pb,Ca,Ba)U_3SiO_{12} \cdot 6H_2O$	Amorph.
1157. Yttrogummite	$(Pb,Ca,Ba)U_3SiO_{12} \cdot 6H_2O+Y$	Earthy
1158. Thorogummite	$(Pb,Ca,Ba)U_3SiO_{12} \cdot 6H_2O+Th$	Earthy
1159. Uranosphaerite	$(BiO)_2U_2O_7 \cdot 3H_2O$	Globular

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
1127.	White	3	3	New Jersey	Manganese
1128.	Green	5	3.9	Hungary	Magnesium
1129.	Black	6	3.8	Sweden	Manganese
1130.	Yellow	5.5	4	Norway	Zinc
1131.	Colorless	6.5	3	Mt. Soktuj	Boron
1132.	White	7.5	2	Norway	Berylium
1133.	White	3	3	Hungary	Boron
1134.	White	7	2.9	France	
1135.	White	.....	1.9	Germany	
1136.	White	8	3	Urals	
1137.	Brown	3	3	New York	
1138.	White	3.5	2	Nova Scotia	
1139.	Yellow	.....	......	Tuscany	
1140.	Yellow	.....	......	Tuscany	
1141.	Colorless	4	2	California	
1142.	Yellow	3	3	Stassfurt	
1143.	Colorless	4	2	Stassfurt	
1144.	White	2	1.6	Nevada	
1145.	White	1	1.6	Nevada	
1146.	Gray	.....	......	Tuscany	
1147.	White	2	1.9	Caucasus	
1148.	Colorless	4	2	Germany	
1149.	Gray	5.5	9	Connecticut	Rare elements
1150.	Gray	5.5	9	Norway	
1151.	Gray	5.5	9	Norway	
1152.	Gray	5.5	7	Norway	
1153.	Black	5.5	8	Texas	
1154.	Black	5.5	8	Colorado	
1155.	Yellow	.....	......	Utah	
1156.	Yellow	2.5	3.9	North Carolina	
1157.	Black	5	......	Norway	
1158.	Brown	4	4	Texas	
1159.	Red	2.3	6	Saxony	

COMPREHENSIVE

	Composition	Form
XI. SULPHATES, ETC.		
1. *Anhydrous Sulphates*		
1160. Mascagnite	$(NH_4)_2SO_4$	Ortho.
1161. Taylorite	$5K_2SO_4 \cdot (NH_4)_2SO_4$	Concret.
1162. Thenardite	Na_2SO_4	Ortho.
1163. Aphthitalite	$(K,Na)_2SO_4$	Hexag.
1164. Glauberite	$Na_2SO_4 \cdot CaSO_4$	Mono.
1165. Langbeinite	$K_2Mg_2(SO_4)_3$	Hexag.
1166. Barite	$BaSO_4$	Ortho.
1167. Bologna stone	$BaSO_4$	Ortho.
1168. Cawk	$BaSO_4$	Ortho.
1169. Michel-levyte	$BaSO_4$	Ortho.
1170. Celestite	$SrSO_4$	Ortho.
1171. Apotome	$SrSO_4$	Ortho.
1172. Anglesite	$PbSO_4$	Ortho.
1173. Anhydrite	$CaSO_4$	Ortho.
1174. Vulpinite	$CaSO_4$	Scaly
1175. Tripstone	$CaSO_4$	Concret.
1176. Zinkosite	$ZnSO_4$	Ortho.
1177. Hydrocyanite	$CuSO_4$	Ortho.
1178. Crocoite	$PbCrO_4$	Mono.
1179. Leadhillite	$4PbO \cdot SO_3 \cdot 2CO_2 \cdot H_2O$	Mono.
1180. Susannite	$4PbO \cdot SO_3 \cdot 2CO_2 \cdot H_2O$	Mono.
1181. Sulphohalite	$3Na_2SO_4 \cdot 2NaCl$	Regular
1182. Caracolite	$Pb(OH)Cl \cdot Na_2SO_4$	Ortho.
1183. Kainite	$MgSO_4 \cdot KCl \cdot 3H_2O$	Mono.
1184. Connellite	$Cu_{15}(Cl,OH)_4SO_{16} \cdot 15H_2O$	Hexag.
1185. Spangolite	$Cu_6AlClSO_{10} \cdot 9H_2O$	Hexag.
1186. Hanksite	$9Na_2SO_4 \cdot 2Na_2CO_3 \cdot KCl$	Hexag.
1187. Misenite	$HKSO_4$	Mono.
1188. Brochantite	$CuSO_4 \cdot 3Cu(OH)_2$	Ortho.
1189. Lanarkite	Pb_2SO_5	Mono.
1190. Dolerophanite	Cu_2SO_5	Mono.
1191. Caledonite	$2(Pb,Cu)O \cdot SO_3 \cdot H_2O$	Ortho.
1192. Linarite	$(Pb,Cu)SO_4 \cdot (Pb,Cu)(OH)_2$	Mono.
1193. Antlerite	$3CuSO_4 \cdot 7Cu(OH)_2$	Massive
1194. Alumian	$Al_2O_3 \cdot 2SO_3$	Hexag.
2. *Hydrous Sulphates*		
a. Normal		
1195. Lecontite	$(Na,NH_4,K)_2SO_4 \cdot 2H_2O$	Ortho.
1196. Mirabilite	$Na_2SO_4 \cdot 10H_2O$	Mono.
1197. Kieserite	$MgSO_4 \cdot H_2O$	Mono.
1198. Szmikite	$MnSO_4 \cdot H_2O$	Amorph.
1199. Gypsum	$CaSO_4 \cdot 2H_2O$	Mono.
1200. Selenite	$CaSO_4 \cdot 2H_2O$	Mono.
1201. Satin spar	$CaSO_4 \cdot 2H_2O$	Mono.
1202. Alabaster	$CaSO_4 \cdot 2H_2O$	Mono.
1203. Ilesite	$(Mn,Zn\ Fe)SO_4 \cdot 4H_2O$	Mono.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
1160.	Yellow	2	1.7	Etna	Sulphur
1161.	White	2	......	Chincha Islands	
1162.	White	2	2	California	Sulphur
1163.	White	3	2	Vesuvius	Potash
1164.	Yellow	2.5	2.7	California	Potassium
1165.	Colorless	.....	2.8	Germany	Manganese
1166.	White	2.5	4	New York	Barium
1167.	Reddish	2.5	4	Bologna	
1168.	Reddish	2.5	4	Bologna	
1169.	Reddish	2.5	4	Quebec	
1170.	White	3	3.9	Texas	Strontium
1171.	White	3	3.9	Texas	
1172.	White	2.7	6	Pennsylvania	Lead
1173.	White	3	2.8	Tennessee	Calcium
1174.	White	3	2.8	Lombardy	
1175.	White	3	2.8	Lombardy	
1176.	White	.....	2.8	Spain	Zinc
1177.	Green	.....	......	Vesuvius	Copper
1178.	Red	2.5	5.9	Arizona	Lead
1179.	Yellow	2.5	6	Scotland	
1180.	Yellow	2.5	6	Scotland	
1181.	Yellow	3	2	California	Sulphur
1182.	Colorless	4.5	......	Atacama	Lead
1183.	White	2	2	Stassfurt	Sulphur
1184.	Blue	3	3	Cornwall	Copper
1185.	Green	2	3	Arizona	
1186.	White	3	2.5	California	Sodium
1187.	White	.....	......	Naples	Potassium
1188.	Green	3.5	3.9	Colorado	Copper
1189.	White	2	5	Scotland	Lead
1190.	Brown	.....	......	Vesuvius	Copper
1191.	Green	2.5	6	California	Lead
1192.	Blue	2	5	California	
1193.	Green	.....	3.9	Arizona	Copper
1194.	White	2	2.7	Spain	Sulphur
1195.	Colorless	2	......	Central America	Sodium
1196.	White	1.5	1	Salt Lake, Utah	
1197.	White	3	2	Stassfurt	Magnesium
1198.	White	1.5	3	Hungary	Manganese
1199.	White	1.5	2	Michigan	Plaster
1200.	White	1.5	2	Michigan	
1201.	White	1.5	2	Michigan	
1202.	White	1.5	2	Michigan	Ornaments
1203.	Green	.....	......	Colorado	Manganese

		Composition	Form
XI.	SULPHATES, ETC.—*continued*		
1204.	Epsomite	$MgSO_4 \cdot 7H_2O$	Ortho.
1205.	Goslarite	$ZnSO_4 \cdot 7H_2O$	Ortho.
1206.	Morenosite	$NiSO_4 \cdot 7H_2O$	Ortho.
1207.	Melanterite	$FeSO_4 \cdot 7H_2O$	Mono.
1208.	Mallardite	$MnSO_4 \cdot 7H_2O$	Mono.
1209.	Pisanite	$(Fe,Cu)SO_4 \cdot 7H_2O$	Mono.
1210	Salvadorite	$(Cu,Fe)SO_4 \cdot 7H_2O$	Mono.
1211.	Bieberite	$CoSO_4 \cdot 7H_2O$	Mono.
1212.	Chalcanthite	$CuSO_4 \cdot 5H_2O$	Triclinic
1213.	Syngenite	$CaSO_4 \cdot K_2SO_4 \cdot H_2O$	Mono.
1214.	Löweite	$MgSO_4 \cdot Na_2SO_4 \cdot 2\frac{1}{2}H_2O$	Tetrag.
1215.	Blödite	$MgSO_4 \cdot Na_2SO_4 \cdot 4H_2O$	Mono.
1216.	Leonite	$MgSO_4 \cdot K_2SO_4 \cdot 4H_2O$	Mono.
1217.	Boussingaultite	$(NH_4)_2SO_4 \cdot MgSO_4 \cdot 6H_2O$	Mono.
1218.	Picromerite	$MgSO_4 \cdot K_2SO_4 \cdot 6H_2O$	Mono.
1219.	Polyhalite	$2CaSO_4 \cdot MgSO_4 \cdot K_2SO_4 \cdot 2H_2O$	Mono.
1220.	Pickeringite	$MgSO_4 \cdot Al_2(SO_4)_3 \cdot 22H_2O$	Mono.
1221.	Halotrichite	$FeSO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$	Mono.
1222.	Apjohnite	$MnSO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$	Mono.
1223.	Dietrichite	$(Zn,Fe,Mn)SO_4 \cdot Al_2(SO_4)_3 \cdot 22H_2O$	Mono.
1224.	Masrite	Fe,Ms,Mn,Co,Al, sulphate	Fibrous
1225.	Coquimbite	$Fe_2(SO_4)_3 \cdot 9H_2O$	Hexag.
1226.	Quenstedtite	$Fe_2(SO_4)_3 \cdot 10H_2O$	Mono.
1227.	Ihlëite	$Fe_2(SO_4)_3 \cdot 12H_2O$	Efflor.
1228.	Alunogen	$Al_2(SO_4)_3 \cdot 18H_2O$	Mono.
1229.	Kröhnkite	$CuSO_4 \cdot Na_2SO_4 \cdot 2H_2O$	Mono.
1230.	Phillipite	$CuSO_4 \cdot Fe_2(SO_4)_3 \cdot nH_2O$	Mono.
1231.	Ferronatrite	$3Na_2SO_4 \cdot Fe_2(SO_4)_3 \cdot 6H_2O$	Hexag.
1232.	Römerite	$FeSO_4 \cdot Fe_2(SO_4)_3 \cdot 12H_2O$	Triclinic
1233.	Natrochalcite	$Na_2SO_4 \cdot Cu_4(OH)_2(SO_4)_2 \cdot 2H_2O$	Mono.
	b. Basic		
1234.	Langite	$CuSO_4 \cdot 3Cu(OH)_2 \cdot H_2O$	Ortho.
1235.	Herrengrundite	$2(CuOH)_2SO_4 \cdot Cu(OH)_2 \cdot 3H_2O$	Mono.
1236.	Kamarezite	$(CuOH)_2SO_4 \cdot Cu(OH)_2 \cdot 6H_2O$	Ortho.
1237.	Cyanotrichite	$4CuO \cdot Al_2O_3 \cdot SO_3 \cdot 8H_2O$	Ortho.
1238	Serpierite	Cu,Zn, sulphate	Ortho.
1239.	Copiapite	$2Fe_2O_3 \cdot 5SO_3 \cdot 18H_2O$	Mono.
1240.	Castanite	$Fe_2O_32SO_3 \cdot 8H_2O$	Mono.
1241.	Utahite	$3Fe_2O_3 \cdot 2SO_3 \cdot 7H_2O$	Hexag.
1242.	Amarantite	$Fe_2O_3 \cdot 2SO_3 \cdot 7H_2O$	Triclinic
1243.	Fibroferrite	$Fe_2O_3 \cdot 2SO_3 \cdot 10H_2O$	Mono.
1244.	Raimondite	$2Fe_2O_3 \cdot 3SO_37H_2O$	Hexag.
1245.	Carphosiderite	$3Fe_2O_3 \cdot 4SO_3 \cdot 10H_2O$	Hexag.
1246.	Glockerite	$2Fe_2O_3 \cdot SO_3 \cdot 6H_2O$	Earthy
1247.	Knoxvillite	Cr,Fe,Al,H, sulphate	Ortho.
1248.	Redingtonite	Cr,Fe,Al,H, sulphate	Ortho.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
1204.	White	2	1.7	Kentucky	Medicine
1205.	White	2	1.9	Montana	Zinc
1206.	Green	2	2	Galicia	Nickel
1207.	Green	2	1.8	Utah	Iron
1208.	Colorless	.....	......	Utah	Manganese
1209.	Blue	.....	......	Turkey	Copper
1210.	Green	.....	......	Chile	
1211.	Red	.....	1.9	Bieber	Cobalt
1212.	Blue	2.5	2	Arizona	Copper
1213.	Colorless	2	2	Galicia	Potassium
1214.	Yellow	2	2	Austria	Sodium
1215.	Colorless	2	2	Chile	Magnesium
1216.	White	.....	......	Germany	Potassium
1217.	White	.....	1.6	Tuscany	Magnesium
1218.	White	.....	2	Vesuvius	Potassium
1219.	Red	2	2	Austria	Calcium
1220.	White	1	......	Colorado	Aluminum
1221.	Yellow	.....	......	New Mexico	
1222.	Yellow	1.5	1.7	Tennessee	
1223.	Yellow	2	......	Hungary	
1224.	....	.....	......	Egypt	....
1225.	White	2	2	Chile	Iron
1226.	Red	2	2	Chile	
1227.	Yellow	.....	1.8	Bohemia	
1228.	White	1.5	1.6	Bohemia	Aluminum
1229.	Blue	2.5	1.9	Atacama	Copper
1230.	Blue	.....	......	Chile	
1231.	Gray	2	2	Chile	Sodium
1232.	Brown	3	2	Chile	Iron
1233.	Green	4	2	Chile	Copper
1234.	Blue	2	3	Cornwall	Copper
1235.	Green	2	3	Hungary	
1236.	Green	3	3	Greece	
1237.	Blue	.....	......	Utah	
1238.	Green	.....	......	Greece	
1239.	Yellow	2.5	2	Chile	Iron
1240.	Brown	3	2	Chile	
1241.	Yellow	.....	......	Utah	
1242.	Red	2	2	Chile	
1243.	Yellow	2	1.8	Chile	
1244.	Yellow	3	3	Bolivia	
1245.	Yellow	4	2	Greenland	
1246.	Brown	.....	......	Harz	
1247.	Yellow	.....	......	California	
1248.	Pale purple	.....	1.7	Knoxville	Chromium

		Composition	Form
XI.	SULPHATES, ETC.—*continued*		
1249.	Cyprusite	$7Fe_2O_3 \cdot Al_2O_3 \cdot 10SO_3 \cdot 14H_2O$	Hexag.
1250.	Aluminite	$Al_2O_3 \cdot SO_8 \cdot 9H_2O$	Mono.
1251.	Paraluminite	$2Al_2O_3 \cdot SO_3 \cdot 15H_2O$	Mono.
1252.	Felsöbanyite	$2Al_2O_3 \cdot SO_3 \cdot 10H_2O$	Ortho.
1253.	Botryogen	$MgO \cdot FeO \cdot Fe_2O_34SO_3 \cdot 18H_2O$	Mono.
1254.	Sideronatrite	$2Na_2O \cdot Fe_2O_34SO_3 \cdot 7H_2O$	Ortho.
1255.	Voltaite	$5(K_2,Fe)O \cdot 2(Al,Fe)_2O_3 \cdot 10SO_3 \cdot 15H_2O$	Regular
1256.	Metavoltine	$5(Ka_2Na_2,Fe)O \cdot 3F_2O_3 \cdot 12SO_3 \cdot 18H_2O$	Hexag.
1257.	Alunite	$K_2O \cdot 3Al_2O_3 \cdot 4SO_3 \cdot 6H_2O$	Hexag.
1258.	Jarosite	$K_2O \cdot 3Fe_2O_3 \cdot 4SO_3 \cdot 6H_2O$	Hexag.
1259.	Lowigite	$K_2O \cdot 3Al_2O_3 \cdot 4SO_3 \cdot 9H_2O$	Hexag.
1260.	Ettringite	$6CaO \cdot Al_2O_3 \cdot 3SO_3 \cdot 33H_2O$	Hexag.
1261.	Quetenite	$MgO \cdot Fe_2O_3 \cdot 3SO_3 \cdot 13H_2O$	Mono.
1262.	Zincaluminite	$2ZnSO_4 \cdot 4Zn(OH)_2 \cdot 6Al(OH)_3 \cdot 5H_2O$	Hexag.
1263.	Johannite	U,Cu,H, sulphate	Mono.
1264.	Uranopilite	$CaU_8S_2O_{31} \cdot 25H_2O$	Incrust.
	3. *Tellurates*		
1265.	Montanite	$Bi_2O_3 \cdot TeO_3 \cdot 2H_2O$	Earthy
1266.	Emmonsite	Fe,H, tellurate	Mono.
1267.	Durdenite	$Fe_2(TeO_3)_3 \cdot 4H_2O$	Massive
1268.	Chalcomenite	$CuSeO_3 \cdot 2H_2O$	Mono.
1269.	Molybdomenite	Pb, selenite	Ortho.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
1249.	Yellow	2	......	Cyprus	Iron
1250.	White	1	1	Halle	Aluminum
1251.	White	.....	......	Halle	
1252.	Snow white	1	2	Hungary	
1253.	Red	2	2	Sweden	Iron
1254.	Yellow	2	2	Chile	
1255.	Green	3	2	Naples	
1256.	Yellow	2	2	Persia	
1257.	White	3.5	2.5	Colorado	Aluminum
1258.	Yellow	2.5	3	Utah	Iron
1259.	Yellow	3	2	Upper Silesia	Aluminum
1260.	Colorless	2	1.7	Prussia	Calcium
1261.	Brown	3	2	Chile	Iron
1262.	White	2	2	Greece	Zinc
1263.	Green	2	3	Joachimsthal	Uranium
1264.	Yellow	.....	3	Johanngeorgenst'dt	
1265.	Yellow	.....	......	Montana	Bismuth
1266.	Green	5	......	Arizona	Tellurium
1267.	Yellow	2	......	Honduras	
1268.	Blue	.....	3	Argentina	Selenium
1269.	White	.....	......	Argentina	

	Composition	Form
XII. TUNGSTATES, MOLYBDATES		
1270. Wolframite	$(Fe,Mn)WO_4$	Mono.
1271. Hübnerite	$MnWO_4$	Mono.
1272. Scheelite	$CaWO_4$	Tetrag.
1273. Cuprotungstite	$CuWO_4$	Crystal.
1274. Powellite	$CaMoWO_4$	Tetrag.
1275. Stolzite	$PbWO_4$	Tetrag.
1276. Raspite	$PbWO_4$	Mono.
1277. Wulfenite	$PbMoO_4$	Tetrag.
1278. Reinite	$FeWO_4$	Tetrag.
1279. Belonesite	$MgMoO_4$	Tetrag.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
1270.	Black	5	7	Connecticut	Tungsten
1271.	Brown	5·5	7	Nevada	
1272.	White	4·5	5·9	North Carolina	
1273.	Green	4	......	Chile	
1274.	Yellow	3·5	4	Michigan	Molybdenum
1275.	Green	2.7	7.8	Zinnwald	Tungsten
1276.	Yellow	2	......	New South Wales	
1277.	Green	2.7	6.7	Arizona	Molybdenum
1278.	Brown	4	6.6	Japan	Tungsten
1279.	White	.....	......	Vesuvius	Molybdenum

	Composition	Form
XIII. ORGANIC ACIDS		
Oxalates, Mellates		
1280. Whewellite..........	$CaC_2O_4 \cdot H_2O$	Mono.
1281. Oxammite..........	$(NH_4)_2C_2O_4 \cdot 2H_2O$	Ortho.
1282. Humboldtine........	$2FeC_2O_4 \cdot 3H_2O$	Capill.
1283. Mellite.............	$Al_2C_{12}O_{12} \cdot 18H_2O$	Tetrag.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
1280.	Colorless	2.5	......	Saxony	Calcium
1281.	Yellowish	.....	......	Peru	Ammonium
1282.	Yellow	2	2	Bohemia	Iron
1283.	Yellow	2	1.5	Bohemia	Mellitic acid

		Composition		Form
XIV. HYDROCARBONS				
1284.	Scheererite	C_nH_m		Mono.
1285.	Hatchettite	C_nH_m.	C=85%; H=15%	Mono.
1286.	Paraffin	C_nH_m.	C=85%; H=15%	Amorph.
1287.	Ozocerite	C_nH_m.	C=86%; H=14%	Amorph.
1288.	Zietrisikite	C_nH_m.	C=84.6%; H=15.4%	Amorph.
1289.	Chrismatite	C_nH_m.	C=80%; H=20%	Amorph.
1290.	Urpethite	C_nH_m.	C=85.8%; H=14.2%	Amorph.
1291.	Fichtelite	$C_{15}H_{28}$.	C=87.2%; H=12.8%	Mono.
1292.	Napalite	C_3H_4.	C=89.8%; H=10.2%	Amorph.
1293.	Amber	C_nH_m.	C=78.9%; H=10.5%; O=10.6%	Amorph.
1294.	Succinite	C_nH_m.	C=78.9%; H=10.5%; O=10.6%	Amorph.
1295.	Retinite	C_nH_m		Amorph.
1296.	Gedanite	C_nH_m		Amorph.
1297.	Glessite	C_nH_m		Amorph.
1298.	Rumanite	C_nH_m		Amorph.
1299.	Copalite	C_nH_m.	C=85.6%; H=11.4%; O=3%	Amorph.
1300.	Bathvillite	C_nH_m.	C=59%; H=9%; O=1%; Ash=31%	Amorph.
1301.	Tasmanite	C_nH_m.	C=79%; H=10%; O=5%; S=6%	Scales
1302.	Dysodile	C_nH_m.	C=69%; H=10%; O=16%; S=3%; N=2%	Scales
1303.	Geocerite	$C_{28}H_{56}O_2$.	C=79%; H=13%; O=8%	Waxy
1304.	Leucopetrite	$C_{50}H_{84}O_3$.	C=82%; H=11%; O=7%	Waxy
1305.	Pyroretinite	$C_{40}H_{60}O_4$.	C=80%; H=9%; O=11%	Resinous
1306.	Dopplerite	C_nH_m.	C=51%; H=5%; O=4%; N=1%	Amorph.
1307.	Idrialite	$C_{42}H_{14}O$.	C=91%; H=6%; O=3%	Earthy
1308.	Posepnyte	$C_{22}H_{36}O_4$.	C=72%; H=10%; O=18%	Plates
1309.	Petroleum, naphtha	C_nH_{2n+2}		Amorph.
1310.	Pittasphalt	C_nH_{2n+2}		Viscid
1311.	Asphaltum	C_nH_{2n+2}		Amorph.
1312.	Elaterite	C_nH_{2n+2}		Amorph.
1313.	Albertite	C_nH_{2n+2}		Amorph.
1314.	Grahamite	C_nH_{2n+2}		Amorph.
1315.	Gilsonite	C_nH_{2n+2}		Amorph.
1316.	Mineral coal	C_nH_{2n+2}		Amorph.
1317.	Anthracite	C_nH_{2n+2}		Amorph.
1318.	Bituminous coal	C_nH_{2n+2}		Amorph.
1319.	Coking coal	C_nH_{2n}		Amorph.
1320.	Non-coking coal	C_nH_{2n}		Amorph.
1321.	Cannel coal	C_nH_{2n}		Amorph.
1322.	Torbanite	C_nH_{2n}		Amorph.
1323.	Lignite	C_nH_{2n}		Amorph.
1324.	Jet	C_nH_{2n}		Amorph.
1325.	Peat	C_nH_{2n}		Amorph.

LIST OF MINERALS

No.	Color	Hardness	Gravity	Locality	Chief Constituent or Use
1284.	Resinous	.....	1	Switzerland	Chemicals
1285.	White	1	.9	Switzerland	Paraffin
1286.	Yellowish	.....	......	England	
1287.	Brown	.....	.9	Sicily	Technical purposes
1288.	Brown	.5	.9	Utah	
1289.	Yellow	.....	9	Saxony	
1290.	Brown	.....	.8	Urpeltz	
1291.	White	.....	......	Bavaria	
1292.	Brown	2	......	California	
1293.	Yellow	2	1	Baltic coast	
1294.	Yellow	2	1	Baltic coast	
1295.	Brown	.....	......	Germany	Technical purposes
1296.	Brown	.....	......	Baltic	
1297.	Brown	2	1	Baltic	
1298.	Brown	2	1	Roumania	
1299.	Yellow	.....	1	Tropics	Varnish
1300.	Brown	2	1	Scotland	Technical purposes
1301.	Brown	2	1	Tasmania	
1302.	Yellow	.....	1.2	Sicily	
1303.	White	.....	......	Weissengels	
1304.	White	.....	1.2	Weissengels	
1305.	Yellow	2	1	Bohemia	Technical purposes
1306.	Black	2	1	Styria	
1307.	White	.....	......	Idria	
1308.	Green	.....	.9	California	
1309.	Brown	.....	.6	United States	Oil
1310.	Greenish brown	.....	......	Pennsylvania	
1311.	Black	.....	1	California	Technical purposes
1312.	Brown	.....	9	Derbyshire	
1313.	Black	1	1	Nova Scotia	
1314.	Black	2	1	West Virginia	
1315.	Black	2	1	Utah	
1316.	Black	2.5	1	United States	Fuel
1317.	Black	2	1	Pennsylvania	
1318.	Black	2.5	1	Pennsylvania	
1319.	Black	2	1.5	Virginia	
1320.	Black	2	1.5	Illinois	
1321.	Black	2	1.5	West Virginia	
1322.	Brown	2.2	1.1	Scotland	
1323.	Brown	1.5	1.1	Western states	
1324.	Black	1.5	1.1	Wales	Jewelry
1325.	Brown	1	1.1	Scotland	Fuel

GENERAL INDEX

GENERAL INDEX

The number preceding each mineral is the list number used in the List of Minerals; that following is the page number.

Abbreviations, xxi
590. Abriachanite, 234
774. Acadialite, 242
81. Acanthite, 204
748. Achroite, 240
545. Acmite, 232
565. Actinolite, 232
979. Adamite, 254
969. Adelite, 252
Admire, 44
493. Adularia, 134, 230
593. Aenigmatite, 234
Aerolites, 43
931. Aeschynite, 250
436. Agaric Mineral, 226
291. Agate, 90, 218
Agricola, 198
664. Agricolite, 236
70. Aguilarite, 204
Ahnighito, 43
183. Aikinite, 210
Airy's spiral, 88
90. Alabandite, 206
1202. Alabaster, 264
529. Alalite, 230
1313. Albertite, 274
505. Albite, 140, 230
374. Alexandrite, 222
55. Algodonite, 204
61. Alisonite, 204
998. Allacite, 254
725. Allanite, 240
10. Allemonite, 202
655. Allochroite, 236
139. Alloclasite, 208
31. Allopalladium, 202
883. Allophane, 246
646. Almandite, 159, 236
62. Altaite, 204
1194. Alumian, 264
1250. Aluminite, 268
Aluminium, 45
1257. Alunite, 268
1228. Alunogen, 266
809. Alurgite, 244
21. Amalgam, 202
1242. Amarantite, 266
502. Amazonstone, 230
1293. Amber, 187, 274
975. Amblygonite, 252
830. Amesite, 244
277. Amethyst, 88, 218
567. Amianthus, 232
1108. Ammiolite, 258
Amorphous, 2
563. Amphibole, 152, 232
782. Analcime, 242
781. Analcite, 167, 242
704. Andalusite, 238
511. Andesine, 139, 230
152. Andorite, 210
648. Andradite, 159, 236
1084. Andrewsite, 258
1172. Anglesite, 181, 264
1173. Anhydrite, 264
53. Animikite, 204
1024. Annabergite, 256
929. Annerodite, 250
803. Anomite, 242
514. Anorthite, 139, 142, 230
504. Anorthoclase, 138, 230
561. Anthophyllite, 232
1317. Anthracite, 192, 274
850. Antigorite, 244
Antimonates, 175
12. Antimony, 31, 45, 202
1193. Antlerite, 264
945. Apatite, 175, 252
422. Aphrite, 226
747. Aphrizite, 240
831. Aphrosiderite, 244
1163. Aphthitalite, 264
1222. Apjohnite, 266
658. Aplome, 236
758. Apophyllite, 240
1171. Apotome, 264
596. Aquamarine, 156, 234
450. Aragonite, 122, 226
735. Ardennite, 240
590*a*. Arfedsonite, 234
421. Argentine, 226
66. Argentite, 51, 204
Argon, 45
216. Argyrodite, 212

Aristotle, 198
22. Arquerite, 202
Arsenates, 175
9. Arsenic, 31, 45, 202
1003. Arseniopleite, 254
997. Arseniosiderite, 254
325. Arsenolite, 220
134. Arsenopyrite, 67, 208
567. Asbestus, 155, 232
413. Asbolite, 224
1135. Ascharite, 262
305. Asmanite, 218
616. Aspasiolite, 234
1311. Asphaltum, 188, 274
910. Astrophyllite,248
248. Atacamite, 214
1005. Atelestite, 254
1098. Atopite, 258
1069. Attacolite, 258
699. Auerlite, 238
1066. Augelite, 256
542. Augite, 147, 232
467. Aurichalcite, 228
365. Automolite, 222
1090. Autunite, 258
285. Aventurine, 218
Avicenna, 198
33. Awaruite, 202
Axial plane, 131
727. Axinite, 240
465. Azurite, 130, 228

Babbitt metal, 32
559. Babingtonite, 232
389. Baddeleyite, 222
726. Bagrationite, 240
536. Baikalite, 232
Bayly, W. S., ix, 200
1166. Barite, 179, 264
Barium, 45
592. Barkevikite, 234
1032. Barrandite, 256
Bartholinus, 112, 198
621. Barylite, 234
618. Barysilite, 234
457. Barytocalcite, 226
297. Basanite, 218
Base, 28
Basic Phosphates, 256
524. Bastite, 230
847. Bastite, 244
460. Bastnasite, 226
1300. Bathvillite, 274
401. Bauxite, 222
Baveno Twin, 134
1049. Bayldonite, 256
Bayley, W. S., ix, 200
1146. Bechilite, 262
203. Beegerite, 212
1279. Belonesite, 270
896. Bementite, 246
1073. Beraunite, 258
584. Bergamaskite, 234
785. Bergmannite, 242
877. Bergseife, 246
1067. Berlinite, 258
159. Berthierite, 210
739. Bertrandite, 240
594. Beryl, 156, 234
Beryllium, 45
944. Beryllonite, 252
71. Berzelianite, 204
937. Berzeliite, 252
Berzelius, 199
1113. Beudantite, 260
100. Beyrichite, 206
Biaxial, 89
1211. Bieberite, 266
1099. Bindheimite, 258
166. Binnite, 210
Biot, 170
801. Biotite, 170, 242
Bipyramid, 25
Birefringence, 55
262. Bischofite, 214
Bisectrix, 130
329. Bismite, 220
13. Bismuth, 31, 45, 202
44. Bismuthinite, 204
484. Bismutite, 228
129. Bismuto-smaltite, 208
458. Bismutospharite, 226
Bisphenoid, 29
1318. Bituminous coal, 274
381. Bixbyite, 222
Black Jack, 53
1215. Blodite, 266
Board of Museum Advisers, iii
1021. Bobierrite, 254
412. Bog Manganese, 224
397. Bog Ore, 222
876. Bole, 246
249*a*. Boleite, 214
1167. Bologna Stone, 264
610. Bonsdorffite, 234
1134. Boracite, 177, 262
Borates, 177
1144. Borax, 177, 262
1078. Borickite, 258
110. Bornite, 56, 206
Boron, 45
2. Bort, 20, 202
Boston Society, 95
Botryoidal, 89, 99

1253. Botryogen, 268
180. Boulangerite, 210
Bourg de Oisans Twin, 85
182. Bournonite, 210
1217. Boussingaultite, 266
849. Bowenite, 244
Boyle, 198
Brachydome, 26
Brachypinacoid, 27
984. Brackebuschite, 254
1013. Brandite, 254
380. Braunite, 222
Bravais, 199
657. Bredbergite, 236
576. Breislakite, 232
103. Breithauptite, 206
Breithaupt, 199
441. Breunnerite, 226
Brewster, 199
762. Brewsterite, 242
1188. Brochantite, 264
1151. Broggerite, 262
Bromine, 45
454. Bromlite, 226
230. Bromyrite, 214
173. Brongniardite, 210
522. Bronzite, 230
391. Brookite, 222
Brown, A. P., 200
403. Brucite, 222
Brush, 200
1040. Brushite, 256
Buck and Company, ix
720. Bucklandite, 240
301. Buhrstone, 218
Bunsen, 199
341. Bunsenite, 220
557. Bustamite, 232
Butler, G. M., 200
512. Bytownite, 139

1025. Cabrerite, 256
315. Cacholong, 218
1072. Cacoxenite, 258
Cadmium, 45
Caesium, 45
280. Cairngorm, 88, 218
1320. Caking coal, 274
740. Calamine, 240
143. Calaverite, 208
1077. Calcioferrite, 258
983. Calciovolborthite, 254
415. Calcite, 112, 226
Calcium, 45
434. Calc-sinter, 226
434. Calc-Tufa, 116
1191. Caledonite, 264
1034. Callanite, 256
221. Calomel, 214
959. Campylite, 252
532. Canaanite, 232
Canada balsam, 129
628. Cancrinite, 236
217. Canfieldite, 212
1321. Cannel coal, 274
Canon Diablo, 44
602. Cappelenite, 234
1182. Caracolite, 264
Carbon, 45
3. Carbonado, 20, 202
Carbonates, 112
Carlsbad Twin, 134
939. Carminite, 252
260. Carnallite, 214
287. Carnelian, 90, 218
1155. Carnotite, 262
742. Carpholite, 240
1245. Carphosiderite, 266
114. Carrollite, 206
604. Caryocerite, 234
897. Caryopilite, 246
382. Cassiterite, 107, 222
1240. Castanite, 266
806. Caswellite, 242
601. Catapleiite, 234
284. Cat's-eye, 218
375. Cat's Eye, 222
1168. Cawk, 264
866. Celadonite, 246
1170. Celestite, 180, 264
517. Celsian, 230
886. Çenosite, 246
228. Cerargyrite, 214
744. Cerite, 240
Cerium, 45
456. Cerussite, 127, 226
333. Cervantite, 220
360. Ceylonite-Pleonaste, 220
773. Chabazite, 242
1212. Chalcanthite, 266
286. Chalcedony, 89, 218
77. Chalcocite, 52, 57, 204
1268. Chalcomenite, 268
409. Chalcophanite, 224
1055. Chalcophyllite, 256
115. Chalcopyrite, 57, 206
1083. Chalcosiderite, 258
157. Chalcostibite, 210
336. Chalcotrichite, 220
429. Chalk, 226
840. Chamosite, 244
1081. Chenevixite, 258
296. Chert, 90
466. Chessylite, 228

Chester, 124
503. Chesterlite, 230
705. Chiastolite, 238
1074. Childrenite, 258
57. Chilenite, 204
246. Chiolite, 214
148. Chiviatite, 210
521. Chladnite, 230
239. Chloralluminite, 214
Chlorine, 45
814. Chloritoid, 244
237. Chloromagnesite, 214
549. Chloromelanite, 232
890. Chloropal, 246
836. Chlorophaeite, 244
615. Chlorophyllite, 234
361. Chlorospinel, 222
991. Chondrarsenite, 254
731. Chondrodite, 240
1289. Chrismatite, 274
372. Chromite, 104, 107, 222
Chromium, 45
373. Chrysoberyl, 222
889. Chrysocolla, 246
665. Chrysolite, 236
288. Chrysoprase, 90, 218
852. Chrysotile, 244
1028. Churchite, 256
879. Cimolite, 246
94. Cinnabar, 55, 206
640. Cinnamon-Stone, 236
996. Cirrolite, 254
279. Citrine, 88, 218
209. Clarite, 212
326. Claudetite, 220
63. Clausthalite, 204
354. Clay Iron-stone, 220
398. Clay-ironstone, 222
Cleavage, 16
508. Cleavelandite, 230
1152. Cleveite, 262
4. Cliftonite, 202
821. Clinochlore, 244
987. Clinoclasite, 254
Clinodomes, 129
741. Clinohedrite, 240
733. Clinohumite, 240
Clinopinacoid, 129
722. Clinozoisite, 240
Cloisonné work, 33
1316. Coal, 190
Cobalt, 45
119. Cobaltite, 206
537. Coccolite, 232
130. Cockscomb pyrite, 65
1065. Coeruleolactite, 256
39. Cohenite, 202
1319. Coking Coal, 274
1141. Colemanite, 177, 262
Colloidal Silica, 90
1007. Collophanite, 254
884. Collyrite, 246
651. Colophonite, 236
89. Coloradoite, 206
925. Columbite-Tantalite, 250
Columbium, 45
352. Columnar hematite, 220
Comprehensive list, 201
1048. Conichalcite, 256
863. Connarite, 246
1184. Connellite, 264
1299. Copalite, 274
1239. Copiapite, 266
18. Copper, 38, 45, 202
1225. Coquimbite, 266
1052. Cornwallite, 256
829. Corundophilite, 244
346. Corundum, 94, 220
121. Corynite, 206
171. Cosalite, 210
243. Cotunnite, 214
687. Couseranite, 238
95. Covellite, 206
Crayon, 173
378. Crednerite, 222
306. Cristobalite, 218
589. Crocidolite, 234
1178. Crocoite, 264
Cronstedt, 198
838. Cronstedite, 244
75. Crookesite, 204
591. Crossite, 234
245. Cryolite, 80, 214
Crystal form, 2
113. Cubanite, 206
Cube, 33
Cullinan diamond, 22
249*b*. Cumengite, 214
572. Cummingtonite, 232
335. Cuprite, 92, 220
149. Cuprobismutite, 210
233. Cuproiodargyrite, 214
60. Cuproplumbite, 204
1273. Cuprotungstite, 270
730. Cuspidine, 240
707. Cyanite, 163, 238
1237. Cyanotrichite, 266
516. Cyclopite, 230
219. Cylindrite, 212
694. Cyprine, 238
1249. Cyprusite, 268

792. Damourite, 242
Dana, ix, 199
135. Danaite, 208
635. Danalite, 236
700. Danburite, 238
573. Dannemorite, 232
1123. Darapskite, 260
708. Datolite, 238
Daubree, 109, 199
259. Daubreeite, 214
112. Daubreelite, 206
597. Davidsonite, 234
255. Daviesite, 214
470. Dawsonite, 228
982. Dechenite, 254
833. Delessite, 244
650. Demantoid, 236
1105. Derbylite, 258
Des Cloizeaux, 199
980. Descloizite, 254
1110. Destinezite, 260
855. Deweylite, 246
832. Diabantite, 244
1109. Diadochite, 260
538. Diallage, 232
1. Diamond, 5, 202
177. Diaphorite, 210
393. Diaspore, 222
Dichroscope, 96
1010. Dickinsonite, 254
1223. Dietrichite, 266
1126. Dietzeite, 260
989. Dihydrite, 254
Dimorphism, 123
527. Diopside, 147, 230
678. Dioptase, 238
Dioscorides, 61
Dioxides, 107
Diploid, 62
686. Dipyre, 238
Dispersion, 19
Disulphides, 206
Ditetragonal Bipyramid, 58
Ditetragonal Prism, 58
Ditrigonal polar, 166
Doctor of Medicine, 3
Dodecahedron, 72
416. Dog-tooth Spar, 226
1190. Dolerophanite, 264
439. Dolomite, 117, 226
Dome, 26
54. Domeykite, 204
1306. Dopplerite, 274
Double refraction, 55
261. Douglasite, 214
Drills, 20
993. Dufrenite, 254
169. Dufrenoysite, 210
749. Dumortierite, 240
974. Durangite, 252
1267. Durdenite, 268
917. Dysanalyte, 248
50. Dyscrasite, 204
366. Dysluite, 222
1302. Dysodile, 274
Dysprosium, 45

953. Earthy Apatite; Osteolite, 252
1102. Ecdemite, 258
578. Edenite, 232
783. Edingtonite, 242
624. Elaeolite, 234
Elasticity coefficient, 119
1312. Elaterite, 274
16. Electrum, 202
Elements, 4
Elements, List of, 5, 45
600. Elpidite, 234
229. Embolite, 214
181. Embrithite, 210
595. Emerald, 156, 234
349. Emery, 94, 220
1266. Emmonsite, 268
156. Emplectite, 210
208. Enargite, 212
960. Endlichite, 252
520. Enstatite, 146, 230
Entantiomorphous, 86
1075. Eosphorite, 258
213. Epiboulangerite, 212
834. Epichlorite, 244
491. Epididymite, 230
717. Epidote, 238
214. Epigenite, 212
763. Epistilbite, 242
1204. Epsomite, 266
Erbium, 45
988. Erinite, 254
Erni, 200
Erubiscite, 56
1023. Erythrite, 254
264. Erythrosiderite, 216
98. Erythrozincite, 206
613. Esmarkite, 234
1260. Ettringite, 268
73. Eucairite, 204
1047. Euchroite, 256
599. Eucolite, 234
710. Euclase, 238
626. Eucryptite, 236
598. Eudialyte, 234
636. Eulytite, 236
951. Eupyrchroite, 252
835. Euralite, 244

Europium, 45
981. Eusynchite, 254
933. Euxenite, 250
1064. Evansite, 256
Extraordinary ray, 55

195. Fahlerz, 74
611. Fahlunite, 234
1014. Fairfieldite, 254
192. Falkenhaynite, 212
211. Famantinite, 212
Farrington, O. C., ix, 200
544. Fassaite, 232
672. Fayalite, 238
1252. Felsobanyite, 268
923. Fergusonite, 250
Ferrites, 104
1231. Ferronatrite, 266
1243. Fibroferrite, 266
1291. Fichtelite, 274
253. Fiedlerite, 214
1011. Fillowite, 254
Finds, 43
310. Fire Opal, 218
1058. Fischerite, 256
1000. Flinkite, 254
295. Flint, 218
322. Float stone, 220
451. Flosferri, 226
266. Fluellite, 216
Fluorescence, 79
Fluorine, 45
257. Fluocerite, 214
235. Fluorite, 78, 214
419. Fontainebleau Limestone, 226
Foote, W. M., ix
273. Footeite, 216
1044. Forbesite, 256
Ford, 199, 200
Forest, 3
670. Forsterite, 236
Fossil resins, 187
Fouque, 199
558. Fowlerite, 232
Fracture, 16
218. Franckeite, 212
948. Francolite, 252
369. Franklinite, 106, 222
196. Freibergite, 212
176. Freieslebenite, 210
860. French chalk, 246
679. Friedelite, 238
80. Frieseite, 204
796. Fuchsite, 242
869. Fuller's Earth, 174
Fulton, 200
711. Gadolinite, 238
Gadolinium, 45
364. Gahnite, 222
59. Galena, 48, 204
158. Galenobismutite, 210
Gallium, 45
619. Ganomalite, 234
755. Ganophyllite, 240
638. Garnet, 158, 236
857. Garnierite, 246
588. Gastaldite, 234
475. Gay Lussite, 228
270. Gearksutite, 216
1296. Gedanite, 274
562. Gedrite, 232
692. Gehlenite, 238
Geikielite, 248
918. Geikielite, 248
General Guide, v
856. Genthite, 246
1303. Geocerite, 274
202. Geocronite, 212
1122. Gerhardtite, 260
Germanium, 45
120. Gersdorffite, 206
133. Geyerite, 208
321. Geyserite, 92, 218
Ghost quartz, 87
405. Gibbsite, 222
625. Gieseckite, 236
794. Gilbertite, 242
1315. Gilsonite, 274
311. Girasol, 218
768. Gismondite, 242
1164. Glauberite, 264
138. Glaucodot, 208
684. Glaucolite, 238
867. Glauconite, 246
587. Glaucophane, 234
326. Glaudetite, 220
1297. Glessite, 274
Glide planes, 47
1246. Glockerite, 266
Glucinum, 45
778. Gmelinite, 242
Goethe, 102
394. Goethite, 101, 222
15. Gold, 32, 45, 202
1205. Goslarite, 266
1086. Goyazite, 258
1314. Grahamite, 274
893. Graminite, 246
5. Graphite, 23, 202
Gratacap, 200
96. Greenockite, 206
905. Greenovite, 248
639. Grossularite, 159, 236

Groth, ix, 200
906. Grothite, 248
107. Grunauite, 206
574. Grunerite, 232
86. Guadalcazarite, 206
45. Guanajuatite, 204
908. Guarinite, 248
187. Guitermanite, 210
1156. Gummite, 262
1199. Gypsum, 182, 264
757. Gyrolite, 240

Haidinger, 65
1038. Haidingerite, 256
224. Halite, 76, 214
872. Halloysite, 246
Haloids, 76
1221. Halotrichite, 266
1132. Hambergite, 262
973. Hamlinite, 252
Hancock County, 87
1186. Hanksite, 264
972. Harderite, 252
Hardin County, 79
Hardness, Scale of, 17
766. Harmotome, 242
729. Harstigite, 240
586. Hastingsite, 234
1285. Hatchettite, 274
920. Hatchettolite, 250
101. Hauchecornite, 206
117. Hauerite, 206
Haüy, 198
631. Haüynite, 236
804. Haughtonite, 242
376. Hausmannite, 222
775. Haydenite, 242
Heat conductivity, 30
534. Hedenbergite, 232
962. Hedyphane, 252
1143. Heintzite, 262
290. Heliotrope, 90
Helium, 45
634. Helvite, 236
1046. Hemafibrite, 256
350. Hematite, 97, 220
1001. Hematolite, 254
Hemihedral, 70
Hemimorphic, 93
Hennepin, 191
1082. Henwoodite, 258
130. Hepatic Pyrite, 64
363. Heroynite, 222
1235. Herrengrundite, 266
777. Herschelite, 242
68. Hessite, 204
Hexagonal system, 68
Hexatetrahedron, 15
Hexoctahedron, 12
761. Heulandite, 242
547. Hiddenite, 232
930. Hielmite, 250
247. Hieratite, 214
560. Hiortdahlite, 232
895. Hisingerite, 246
History of Study of Minerals, 198
894. Hoeferite, 246
1022. Hoernesite, 254
Holbrook, 44
Holland, J. G., 33
Holoaxial, 82
Homestead, 44
709. Homilite, 238
Hope diamond, 22
1009. Hopeite, 254
105. Horbachite, 206
577. Hornblende, 153, 232
296. Hornstone, 90, 218
51. Horsfordite, 204
671. Hortonolite, 236
Hours, iii
1138. Howlite, 262
225. Huantajayite, 214
1271. Hübnerite, 270
837. Hullite, 244
691. Humboldtilite, 238
1282. Humboldtine, 272
732. Humite, 240
52. Huntilite, 204
1043. Hureaulite, 256
Hutchinson, Charles F., iii
Huygens, 112
641. Hyacinth, 236
696. Hyacinth, 238
319. Hyalite, 218
500. Hyalophane, 138, 230
667. Hyalosiderite, 236
620. Hyalotekite, 234
Hydrated sesquioxides, 100
428. Hydraulic limestone, 226
Hydrous Sulphates, 264
1147. Hydroboracite, 262
Hydrocarbons, 187
469. Hydrocerussite, 228
1177. Hydrocyanite, 264
Hydrofluoric acid, 81
Hydrogen, 45
479. Hydrogiobertite, 228
478. Hydromagnesite, 228
790. Hydronephelite, 242
313. Hydrophene, 218
236. Hydrophilite, 214
407. Hydrotalcite, 224

Hydrous carbonates, 228
Hydrous chlorides, 214
Hydrous oxides, 222
468. Hydrozincite, 228
523. Hypersthene, 146, 230

338. Ice, 220
418. Iceland Spar, 115, 226
Iddings, J. P., 200
668. Iddingsite, 236
1307. Idrialite, 274
1227. Ihleite, 266
1203. Ilesite, 264
387. Ilmenorutile, 222
356. Ilmenite, 220
734. Ilvaite, 240
874. Indianaite, 246
515. Indianite, 230
746. Indicolite, 240
Indium, 45
754. Inesite, 240
324. Infusorial Earth, 220
Intermediate plagioclases, 143
Intermediate oxides, 220
Iodine, 45
231. Iodobromite, 214
234. Iodyrite, 214
609. Iolite, 234
26. Iridium, 45, 202
27. Iridosmine, 202
32. Iron, 42, 45, 202
1045. Isoclasite, 256
Isomorphism, 122
300. Itacolumite, 218

371. Jacobsite, 222
Jackson, B. H., 200
Jade, 156
548. Jadeite, 150, 232
67. Jalpaite, 204
168. Jamesonite, 210
697. Jargon, 238
1258. Jarosite, 268
298. Jasper, 90, 218
845. Jefferisite, 244
541. Jeffersonite, 232
1131. Jeremejevite, 262
Jersey County, 40
1324. Jet, 274
1263. Johannite, 268
Jo Daviess County, 49
Johannsen, Albert, 200
911. Johnstrupite, 248
199. Jordanite, 212
47. Joseite, 204
34. Josephinite, 202
Jubilee, 21

585. Kaersutite, 234
1183. Kainite, 264
627. Kaliophilite, 236
124. Kallilite, 206
36. Kamacite, 202
1236. Kamaresite, 266
826. Kammererite, 244
Kaolins, 246
869. Kaolinite, 174, 246
581. Kataforite, 234
1085. Kehoeite, 258
907. Keilhauite, 248
737. Kentrolite, 240
145. Kermesite, 208
1197. Kieserite, 264
204. Kilbrickenite, 212
Kimberley, 5
Kimberlite, 21
Klaproth, 94
165. Klaprotholite, 210
673. Knebelite, 238
916. Knopite, 248
1247. Knoxvillite, 266
172. Kobellite, 210
Kohinoor, 21
579. Koksharovite, 232
23. Kongsbergite, 202
1036. Koninckite, 256
752. Kornerupine, 240
823. Kotschubeite, 244
1026. Kottigite, 256
Kraus, E. H., 200
367. Kreittonite, 222
263. Kremersite, 214
142. Krennerite, 208
1229. Krohnkite, 266
Kryptom, 45
Kunz, G. F., 200
582. Kupfferite, 234

512. Labradorite, 139, 230
Lacroix, ix
1139. Lagonite, 262
414. Lampadite, 224
1189. Lanarkite, 264
763. Langbanite, 240
1165. Langbeinite, 264
1234. Langite, 266
480. Lansfordite, 228
476. Lanthanite, 228
Lanthanum, 45
1140. Larderellite, 262
947. Lasurapatite, 252
772. Laubanite, 242
769. Laumontite, 242
252. Laurionite, 214
126. Laurite, 206

1125. Lautarite, 260
555. Lavenite, 232
533. Lavrovite, 232
242. Lawrencite, 214
743. Lawsonite, 240
Lawyer, 3
994. Lazulite, 254
633. Lazurite, 236
20. Lead, 45, 202
1179. Leadhillite, 264
1195. Lecontite, 264
903. Lederite, 248
72. Lehrbachite, 204
770. Leonhardite, 242
1216. Leonite, 266
799. Lepidolite, 172, 242
808. Lepidomelane, 244
Letter of transmittal, v
543. Leucaugite, 232
822. Leuchtenbergite, 244
518. Leucite, 145, 230
1051. Leucochalcite, 256
1304. Leucopetrite, 274
607. Leucophanite, 234
132. Leucopyrite, 208
779. Levynite, 242
Lewis, J. V., 200
1106. Lewisite, 258
977. Libethenite, 252
486. Liebigite, 228
Liebisch, 199
1323. Lignite, 192, 274
901. Ligurite, 248
186. Lillianite, 210
396. Limonite, 103, 222
1192. Linarite, 264
1114. Lindackerite, 260
111. Linnaeite, 206
Linnaeus, 198
1080. Liroconite, 258
1063. Liskeardite, 256
List of Illustrations, xiii
942. Lithiophilite, 252
Lithium, 45
427. Lithographic Stone, 226
870. Lithomarge, 246
147. Livingstonite, 210
131. Lollingite, 208
Long Island, 44
162. Lorandite, 210
1116. Lossenite, 260
1214. Loweite, 266
1259. Lowigite, 268
497. Loxoclase, 230
1071. Ludlamite, 258
1128. Ludwigite, 262
425. Lumachelle, 226
1115. Lunebergite, 260
Lutecium, 45
210. Luzonite, 212

714. Mackintoshite, 238
Macon County, 40
Macrodome, 27
Macropinacoid, 25
370. Magnesioferrite, 222
440. Magnesite, 120, 226
Magnesium, 45
368. Magnetite, 105, 222
464. Malachite, 128, 228
528. Malacolite, 230
1208. Mallardite, 266
Malus, 112
Manebach Twin, 134
949. Manganapatite, 252
824. Manganchlorite, 244
Manganese, 45
395. Manganite, 100, 222
Manganites, 104
805. Manganophyllite, 242
340. Manganosite, 220
1004. Manganostiibite, 254
130. Marcasite, 63, 208
811. Margarite, 244
793. Margarodite, 242
688. Marialite, 238
83. Marmatite, 206
851. Marmolite, 244
223. Marshite, 214
1041. Martinite, 256
355. Martite, 220
1160. Mascagnite, 264
513. Maskelynite, 230
817. Masonite, 244
1224. Masrite, 266
343. Massicot, 220
160. Matildite, 210
250. Matlockite, 214
140*a*. Maucherite, 208
1107. Mauzeliite, 258
1076. Mazapilite, 258
681. Meionite, 238
652. Melanite, 236
603. Melanocerite, 234
307. Melanophlogite, 218
738. Melanotekite, 240
1207. Melanterite, 266
690. Melilite, 238
608. Meliphanite, 234
1283. Mellite, 272
109. Melonite, 206
251. Mendipite, 214
200. Menenghinite, 212
317. Menilite, 218

19. Mercury, 2, 40, 45, 202
802. Meroxene, 242
Merrill, G. P., 200
442. Mesitite, 226
787. Mesolite, 242
1015. Messelite, 254
85. Metacinnabarite, 206
Metallurgist, 4
Metasilicates, 230
43. Metastibnite, 404
1256. Metavoltine, 268
35. Meteoric Iron, 202
Meteorites, 21, 42
161. Miargyrite, 210
Micas, 168
1169. Michel-levyte, 264
921. Microlite, 250
501. Microcline, 137, 230
629. Microsommite, 236
Miers, ix
232. Miersite, 214
956. Miesite, 252
489. Milarite, 230
314. Milk Opal, 218
281. Milky Quartz, 218
Miller, W. H., 8, 199
99. Millerite, 206
Millspaugh, Charles F., iii
958. Mimetite, 252
Miner, 4
Mineral, Definition of, 1
1316. Mineral coal, 274
Minerals, Abundance of, 1
Minerals, Numbers of, 1
Mineral production of Ill., 1
Minerals, uses of, 1, 287
Minister, 3
377. Minium, 222
Minnesota Mine, 39
1196. Mirabilite, 264
1187. Misenite, 264
Mitscherlich, 199
1097. Mixite, 258
685. Mizzonite, 238
Mohs, 199
Moissan, 199
Molybdates, 270
49. Molybdenite, 204
Molybdenum, 45
331. Molybdite, 220
1269. Molybdomenite, 48, 268
240. Mölysite, 214
936. Monazite, 252
938. Monimolite, 252
Monoclinic axes, 30
Monoclinic system, 30, 129
Monosulphides, 204
Monoxides, 92
1265. Montanite, 268
669. Monticellite, 236
880. Montmorillonite, 246
492. Moonstone, 135
760. Mordenite, 240
1206. Morenosite, 266
Morion, 88
946. Moroxite, 252
912. Mosandrite, 248
986. Mottramite, 254
Moses, A. J., 200
569. Mountain Cork, 156, 232
568. Mountain Leather, 156, 232
Mukerop, 44
498. Murchisonite, 230
791. Muscovite, 168, 242

1101. Nadorite, 258
144. Nagyagite, 208
417. Nail-head Spar, 226
Names of minerals, 196
222. Nantokite, 214
1292. Napalite, 274
1233. Natrochalcite, 266
784. Natrolite, 168, 242
943. Natrophilite, 252
473. Natron, 228
Natural gas, 189
Naumann, 199
65. Naumannite, 204
Neodymium, 45
Neon, 45
898. Neotocite, 246
623. Nephelite, 234
550. Nephrite, 232
566. Nephrite, 156, 232
914. Neptunite, 248
472. Nesquehonite, 228
28. Nevyanskite, 202
1042. Newberyite, 256
878. Newtonite, 246
102. Niccolite, 206
Nickel, 45
128. Nickel-Skutterudite, 208
Nicol prism, 115, 129
386. Nigrine, 222
Niobates, Tantalates, 175
1118. Niter, 260
Nitrates, etc., 260
1121. Nitrobarite, 260
1119. Nitrocalcite, 260
Nitrogen, 45
1124. Nitroglauberite, 260
1120. Nitromagnesite, 260
1153. Nivenite, 262
258. Nocerite, 214

1320. Non-coking coal, 274
891. Nontronite, 246
1130. Nordenskioldine, 262
751. Nordmarkite, 240
462. Northupite, 226
632. Noselite, 236
957. Nussierite, 252

1103. Ochrolite, 258
Octahedron, 5
390. Octahedrite, 222
780. Offretite, 242
756. Okenite, 240
91. Oldhamite, 206
509. Oligoclase, 139, 230
445. Oligonite, 226
976. Olivenite, 252
666. Olivine, 236
539. Omphacite, 232
88. Onofrite, 206
292. Onyx, 90, 218
430. Oolite, 226
308. Opal, 91, 218
316. Opal-agate, 218
854. Ophicalcite, 244
Ordinary ray, 55
Organic acid salts, 187
Orloff, 21
41. Orpiment, 204
492. Orthoclase, 133, 230
Orthodomes, 129
Orthopinacoid, 27
Orthorhombic system, 25
Osmium, 45
818. Ottrelite, 244
Owen, Charles L., iii
Oxalates, Mellates, 272
1281. Oxammite, 272
Oxides, 82
Oxychlorides, 214
Oxygen, 45
789. Ozarkite, 242
1287. Ozocerite, 274

268. Pachnolite, 216
30. Palladium, 45, 202
1286. Paraffin, 274
798. Paragonite, 242
1251. Paraluminite, 268
345. Parameleconite, 220
Parameters, 8
Paramorph, 123
Paramorphism, 123
580. Pargasite, 232
459. Parisite, 226
Parsons, C. L., 200
663. Partschinite, 236
683. Passauite, 238
Payne, Edward W., iii
Peacock ore, 56
206. Pearceite, 212
320. Pearl sinter, 218
Peary, R. E., 43
1325. Peat, 192, 274
525. Peckhamite, 230
552. Pectolite, 232
1059. Peganite, 256
Penfield, S. L., 200
254. Penfieldite, 214
825. Penninite, 244
Pentagonal dodecahedron, 62
92. Pentlandite, 206
Peoria County, 40
Percussion figure, 169
249. Percylite, 214
339. Periclase, 220
507. Pericline, 141, 230
506. Peristerite, 230
915. Perovskite, 248
499. Perthite, 230
488. Petalite, 230
1309. Petroleum. Naphtha, 188, 274
69. Petzite, 204
776. Phacolite, 242
Pharmacist, 3
1037. Pharmacolite, 256
1070. Pharmacosiderite, 258
676. Phenacite, 238
1230. Phillipite, 266
Phillips, A. H., 200
765. Phillipsite, 242
807. Phlogopite, 242
871. Pholerite, 246
868. Pholidolite, 246
461. Phosgenite, 226
Phosphates, 175, 260
Phosphorescence, 19
950. Phosphorite, 252
Phosphorus, 45
1031. Phosphosiderite, 256
1093. Phosphuranylite, 258
820. Phyllite, 244
702. Physalite, 238
1220. Pickeringite, 266
362. Picotite-Chrome Spinel, 222
723. Picroepidote, 240
853. Picrolite, 244
1218. Picromerite, 266
1017. Picropharmacolite, 254
724. Piedmonite, 240
Pinacoid, 27
1129. Pinakiolite, 262
892. Pinguite, 246
797. Pinite, 242

1142. Pinnoite, 262
Pirsson, L. V., 200
474. Pirssonite, 228
1209. Pisanite, 266
431. Pisolite, 155, 226
443. Pistomesite, 226
1154. Pitchblende, 262
1310. Pittasphalt, 274
1111. Pitticite, 260
163. Plagionite, 210
290. Plasma, 218
Plaster of Paris, 182
25. Platinum, 41, 45, 202
Plattner, 199
388. Plattnerite, 222
Pleistocene, 37
38. Plessite, 202
Pliny, 61
1087. Plumbogummite, 258
Polar, 68, 93
384. Polianite, 222
519. Pollucite, 230
656. Polyadelphite, 236
207. Polyargyrite, 212
205. Polybasite, 212
617. Polychroilite, 234
934. Polycrase, 250
106. Polydymite, 206
1219. Polyhalite, 266
932. Polymignite, 250
955. Polysphaerite, 252
Pope County, 79
1308. Posepnyte, 274
Potassium, 45
1274. Powellite, 270
Praeseodymium, 45
289. Prase, 218
309. Precious Opal, 218
Preface, ix
728. Prehnite, 240
Prism, 27
828. Prochlorite, 244
267. Prosopite, 216
Prospector, 4
190. Proustite, 68, 212
84. Przibramite, 206
379. Pseudobrookite, 222
990. Pseudomalachite, 254
Pseudomorph, 123
827. Pseudophite, 244
873. Pseudosteatite, 246
410. Psilomelane, 224
985. Psittacinite, 254
759. Ptilolite, 240
940. Pucherite, 252
703. Pyonite, 238
Pyramid, 25
612. Pyrargillite, 234
189. Pyrargyrite, 68, 210
653. Pyreneite, 236
116. Pyrite, 206
Pyritohedron, 62
408. Pyroaurite, 224
919. Pyrochlore, 250
404. Pyrochroite, 222
392. Pyrolusite, 110, 222
954. Pyromorphite, 176, 252
644. Pyrope, 159, 236
357. Pyrophanite, 220
1008. Pyrophosphorite, 254
882. Pyrophyllite, 246
1305. Pyroretinite, 274
680. Pyrosmalite, 238
193. Pyrostilpnite, 212
526. Pyroxene, 230
Pyroxene group, 145
922. Pyrrhite, 250
104. Pyrrhotite, 55, 206

275. Quartz, 82, 218
303. Quartzine, 218
299. Quartzite, 90, 218
1226. Quenstedtite, 226
1261. Quetenite, 268
Quincy, 124

Radium, 45
1244. Raimondite, 266
271. Ralstonite, 216
Rammelsberg, 199
137. Rammelsbergite, 208
1276. Raspite, 270
170. Rathite, 210
614. Raumite, 234
40. Realgar, 204
353. Red Ocherous hematite, 220
1016. Reddingite, 254
1248. Redingtonite, 266
Refraction, Index of, 18, 19
Regent diamond, 21
Regular system, 16
1278. Reinite, 270
482. Remingtonite, 228
René Just Haüy, 198
Reniform, 99
861. Reneselaerite, 246
312. Resin Opal, 218
Resins, 187
848. Retinalite, 244
1295. Retinite, 274
1002. Retzian, 254
150. Rezbanyite, 210
1027. Rhabdophanite, 256

1096. Rhagite, 258
Radium, 45
1136. Rhodizite, 262
447. Rhodochrosite, 121, 226
645. Rhodolite, 236
556. Rhodonite, 151, 232
Rhombohedron, 70, 114
496. Rhyacolite, 230
1079. Richellite, 258
575. Richterite, 232
588*a*. Riebackite, 234
913. Rinkite, 248
194. Rittingerite, 212
Rock, 2
Rock Island, 124
437. Rock-meal, 226
Roentgen, 47
643. Romanzovite, 236
Romé de L'Isle, 104, 198
622. Roeblingite, 234
1100. Romeite, 258
1232. Romerite, 266
810. Roscoelite, 244
Rose, 198
1012. Roselite, 254
553. Rosenbuschite, 232
278. Rose-quartz, 218
654. Rothoffite, 236
713. Rowlandite, 238
Rubidium, 45
348. Ruby, 95, 220
359. Ruby Spinel-Magnesia Spinel, 220
426. Ruin-marble, 226
1298. Rumanite, 274
843. Rumpfite, 244
Ruthenium, 45
385. Rutile, 109, 222

423. Saccharoidal limestone, 226
136. Safflorite, 208
283. Sagenite, 218
227. Sal Ammoniac, 214
Saline, 44
535. Salite, 232
816. Salmite, 244
1210. Salvadorite, 266
Salt, 76
Salt, Origin of, 77
Salt River, 44
928. Samarekite, 250
Samarium, 45
Sancy, 22
195. Sandbergite, 74
191. Sanguinite, 212
495. Sanidine, 230
865. Saponite, 246
347. Sapphire, 94, 220
282. Sapphire-quartz, 218
753. Sapphirine, 240
689. Sarcolite, 238
293. Sard, 90
293. Sardonyx, 90, 218
Sargasso Seas, 2
971. Sarkinite, 252
155. Sartorite, 210
406. Sassolite, 224
420. Satin Spar, 226
1201. Satin Spar, 264
238. Scacchite, 214
Scalenohedrons, 72, 114
Scandium, 45
175. Schapbachite, 210
1272. Scheelite, 270
1284. Scheererite, 274
540. Schefferite, 232
164. Schirmerite, 210
771. Schneiderite, 242
662. Schorlomite, 236
39*a*. Schreibersite, 202
885. Schrotterite, 246
6. Schungite, 202
256. Schwartzembergite, 214
197. Schwatzite, 74, 212
786. Scolecite, 242
1029. Scorodite, 256
718. Scorza, 238
Selenium, 45
1200. Selenite, 182, 264
8. Selensulphur, 202
241. Sellaite, 214
174. Semseyite, 210
Senarmont, 47
327. Senarmontite, 220
862. Sepiolite, 246
795. Sericite, 242
846. Serpentine, 172, 244
1238. Serpierite, 266
Sesquioxides, 94
812. Seybertite, 244
Shah of Persia, 22
424. Shell-marble, 226
Shepardson, F. W., iii, v
444. Siderite, 120, 226
Siderolites, 43
1254. Sideronatrite, 268
Silicates, 132
294. Siliceous sinter, 218
302. Silicified wood, 218
Silicon, 45
706. Sillimanite, 238
17. Silver, 37, 45, 202
Sinter, 92
924. Sipylite, 250
29. Siserskite, 202

815. Sismondine, 244
127. Skutterudite, 208
118. Smaltite-Chloanthite, 206
570. Smaragdite, 232
875. Smectite, 246
448. Smithsonite, 121, 226
630. Sodalite, 236
1117. Soda Niter, 260
Sodium, 45
Sohncke, 199
Sorby, 199
South Star, 22
864. Spadaite, 246
1185. Spangolite, 264
Spearhead pyrite, 65
Specific gravity, 17
Specific heat, 23
351. Specular hematite, 220
Specularite, 99
125. Sperrylite, 206
647. Spessartite, 159, 236
1062. Sphaerite, 256
449. Sphaerocobaltite, 226
82. Sphalerite, 52, 206
900. Sphene, 248
446. Spherosiderite, 226
358. Spinel, 104, 220
Spinel Twins, 17
902. Spinthere, 248
965. Spodiosite, 252
546. Spodumene, 232
952. Staffelite, 252
432. Stalactites, 116, 226
433. Stalagmite, 116, 226
215. Stannite, 212
276. Star-quartz, 218
750. Staurolite, 240
859. Steatite, 246
Steno, 81, 198
201. Stephanite, 212
1042*a*. Stercorite, 256
79. Sternbergite, 204
334. Stibiconite, 220
42. Stibnite, 46, 204
767. Stilbite, 166, 242
841. Stilpnomelane, 244
881. Stolpenite, 246
1275. Stolzite, 270
383. Stream Tin, 222
605. Streenstrupine, 234
1030. Strengite, 256
842. Strigovite, 244
78. Stromeyerite, 204
455. Strontianite, 126, 226
Strontium, 45
1006. Struvite, 254
58. Stutzite, 204
185. Stylotypite, 210
Subsilicates, 240
Sublimation deposits, 24
642. Succinite, 236
1294. Succinite, 274
1148. Sulfoborite, 262
Sulphantimonites, 68
Sulpharsenates, 212
Sulpharsenites, 68, 210
Sulphates, 179
Sulphides, 46
Sulphides of metals, 204
1181. Sulphohalite, 264
Sulpho-salts, 210
7. Sulphur, 24, 45, 202
Sulphuric acid, 56, 63
220. Sulvanite, 212
Summary, 194
154. Sundtite, 210
510. Sunstone, 230
1180. Susannite, 264
1127. Sussezite, 262
963. Svabite, 252
1112. Svanbergite, 260
108. Sychnodymite, 206
141. Sylvanite, 208
226. Sylvite, 76, 214
Symbol, 8
Symmetry axes, 18
1020. Symplesite, 254
999. Synadelphite, 254
1213. Syngenite, 266
583. Syntagmatite, 234
1133. Szaibelyite, 262
1198. Szmikite, 264

265. Tachhydrite, 216
37. Taenite, 202
1050. Tagilite, 256
858. Talc, 172, 246
967. Talktriplite, 252
272. Tallingite, 216
188. Tapalpite, 210
926. Tapiolite, 250
Tantalum, 45
978. Tarbuttite, 254
452. Tarnowitzite, 226
1301. Tasmanite, 274
995. Tavistockite, 254
1161. Taylorite, 264
Tellurates, 268
330. Tellurite, 220
11. Tellurium, 45, 202
483. Tengerite, 228
198. Tennantite, 212
344. Tenorite, 220
674. Tephroite, 238

Terbium, 45
463. Teschemacherite, 228
46. Tetradymite, 204
195. Tetrahedrite, 72, 212
Tetragonal system, 57
Tetrahedral Twins, 13
Tetrahedron, 13
Tetrahexahedron, 34
719. Thallite, 238
Thallium, 45
887. Thaumasite, 246
1162. Thenardite, 264
471. Thermonatrite, 228
Theophrastus, 99
438. Thinolite, 226
Thin section, 129
269. Thomsenolite, 216
788. Thomsonite, 242
698. Thorite, 238
Thorium, 45
1158. Thorogummite, 262
716. Thulite, 238
Thulium, 45
839. Thuringite, 244
87. Tiemannite, 206
970. Tilasite, 252
337. Tile ore, 220
64. Tilkerodite, 204
24. Tin, 45, 202
Titanates, 248
659. Titaniferous garnet, 236
899. Titanite, 248
Titanium, 45
904. Titanomorphite, 248
701. Topaz, 162, 238
649. Topazolite, 236
1322. Torbanite, 274
1088. Torbernite, 258
745. Tourmaline, 164, 240
Trapezohedron, 9
530. Traversellite, 230
435. Travertine, 116, 226
564. Tremolite, 153, 232
Triassic, 21
1018. Trichalcite, 254
Triclinic system, 139
304. Tridymite, 218
677. Trimerite, 238
941. Triphylite, 252
966. Triplite, 252
968. Triploidite, 252
323. Tripolite, 220
1103*a*. Trippkeite, 258
1175. Tripstone, 264
1104. Tripuhyite, 258
Trisoctahedron, 10
606. Tritomite, 234
1094. Trogerite, 258
93. Troilite, 206
1068. Trolleite, 258
477. Trona, 228
909. Tscheffkinite, 248
Tschermak, ix
1054. Tyrolite, 256
244. Tysonite, 214
Tungstates, 185
Tungsten, 45
332. Tungstite, 220
399. Turgite, 222
1060. Turquois, 256
Tutton, ix

1145. Ulexite, 262
123. Ullmannite, 206
76. Umangite, 204
University of Chicago Press, ix
571. Uralite, 232
Uranates, 177
1149. Uraninite, 178, 262
Uranium, 45
1150. Uranniobite, 262
1159. Uranosphaerite, 262
1091. Uranospinite, 258
1092. Uranocircite, 258
888. Uranophane, 246
1264. Uranopilite, 268
485. Uranothallite, 228
1290. Urpethite, 274
Use of minerals, 197
1241. Utahite, 266
661. Uvarovite, 159, 236

494. Valencianite, 230
328. Valentinite, 220
961. Vanadinite, 252
Vanadium, 45
Van Horn, F. R., 200
1033. Variscite, 256
819. Venasquite, 244
844. Vermiculite, 244
693. Vesuvianite, 238
1056. Veszelyite, 256
Vicinal faces, 78
531. Violan, 230
1019. Vivianite, 254
487. Voglite, 228
1052. Volborthite, 256
1255. Voltaite, 268
146. Voltzite, 208
Von Lang, 146
1174. Vulpinite, 264

411. Wad, 224
964. Wagnerite, 252

1095. Walpurgite, 258
1039. Wapplerite, 256
Ward, Henry B., iii
1061. Wardite, 256
167. Warrenite, 210
1137. Warwickite, 262
1057. Wavellite, 256
153. Webnerite, 210
48. Wehrlite, 204
Welcome Nugget, 35
764. Wellsite, 242
Werner, 199
682. Wernerite, 238
Wherry, E. T., 200
1280. Whewellite, 272
56. Whitneyite, 204
Willamette, 44
675. Willemite, 238
122. Willyamite, 206
Winchell, A. M., and N. H., 200
721. Withamite, 240
453. Witherite, 125, 226
184. Wittichenite, 210
402. Wocheinite, 222
554. Wohlerite, 232
140. Wolfachite, 208
1270. Wolframite, 185, 270
Wollaston, 199
551. Wollastonite, 232
318. Wood Opal, 218
1277. Wulfenite, 186, 270
97. Wurtzite, 206

992. Xantharsenite, 254
813. Xanthophyllite, 244
400. Xanthosiderite, 222
212. Xanthosonite, 212
935. Xenotime, 252

Yellowstone National Park, 24
Ytterbium, 45
660. Yttergranat, 236
712. Yttrialite, 238
Yttrium, 45
274. Yttrocerite, 216
235*a*. Yttrofluorite, 214
1157. Yttrogummite, 262
927. Yttrotantalite, 250

813. Zanthophyllite, 244
481. Zaratite, 228
Zeolites, 166
1035. Zepharovichite, 256
1089. Zeunerite, 258
1288. Zietrisikite, 274
14. Zinc, 45, 202
1262. Zincaluminite, 268
342. Zincite, 93, 220
151. Zinkenite, 210
1176. Zinkosite, 264
800. Zinnwaldite, 242
695. Zircon, 160, 238
Zirconium, 45
Zirkel, 199
715. Zoisite, 238
74. Zorgite, 204
637. Zunyite, 236